CHEMISTRY DEPT.

Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

MAY, 1954

TABLE OF CONTENTS, Page 53

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The WEAN ENGINEERING COMPANY, Inc.
WARREN OHIO

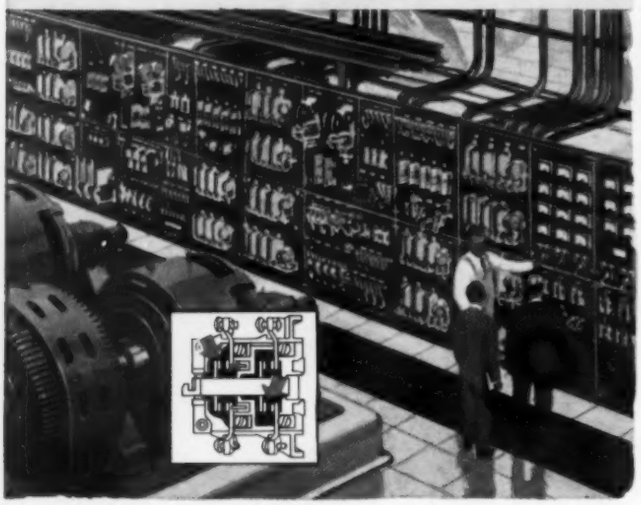
THE THREE CUTLER-HAMMER STARS
★ ★ ★
STAND FOR THREE NEW STANDARDS

Rolling bearing action...

The proper performance and useful life of *all* modern machines demand anti-friction bearings. Motor control is no exception; it too must have good bearings to avoid wear and trouble.

Dust-safe vertical contacts...

Experienced engineers *know* vertical contacts work better and last longer because they stay clean, shed dust, do not collect it. Pressure arc quenching is important new C-H feature.



☆ installs easier
☆ works better
☆ lasts longer

Less bounce by the ounce...

Research showed contact bounce caused arcing, that reduced weight in moving contact members cut bounce and arcing. So new light-weight parts now remarkably lengthen contact life.

Cutler-Hammer Motor Control has always been respected for its long life. It has frequently been chosen for industry's "killer" jobs by comparative test. Many users say, "I have never seen a Cutler-Hammer starter wear out." Yet the new Cutler-Hammer ☆☆☆ Motor Control has *three times* the life of the good equipment it replaces! Nearly unbelievable, but it IS true. Now motor control you can install and forget! Try it. Prove it. Your nearby Cutler-Hammer Authorized Distributor is ready to serve you. Order from him today. CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee 1, Wisconsin.

CUTLER-HAMMER ★★★ MOTOR CONTROL

IRON AND STEEL ENGINEER: published monthly by Association of Iron and Steel Engineers, 1010 Empire Bldg., entered as second class matter January 25, 1924 at Pittsburgh, Pennsylvania under Act of Congress, March 3, 1879. $7.50 per year in United States and Canada, $10.00 foreign countries. Volume 31, No 5.

good equipment keeps production costs DOWN

seamless tube mills
continuous butt weld pipe mills
continuous coating lines
flat-rolled finishing equipment
drawbenches

SUBSIDIARY and ASSOCIATED COMPANIES

Head Wrightson Machine Company, Ltd., Middlesbrough, England — Great Britain, Finland, Sweden, Norway, Denmark, Union of South Africa, Northern and Southern Rhodesia.
Aetna-Standard Engineering Company, Ltd., Toronto, Ontario, Canada.
M. Castellvi, Inc., New York, N. Y. — Mexico, Central and South America.
Societe de Constructions de Montbard, Paris, France — France, Belgium, Holland, Luxembourg, Switzerland.
Demag Aktiengesellschaft, Duisburg, Germany — Germany, Austria, Yugoslavia, Greece, Turkey, Egypt.
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Designers and Builders to the Ferrous, Non-Ferrous, Leather, Rubber, and Plastic Industries

THE AETNA-STANDARD ENGINEERING COMPANY • PITTSBURGH, PA.

Aetna-Standard

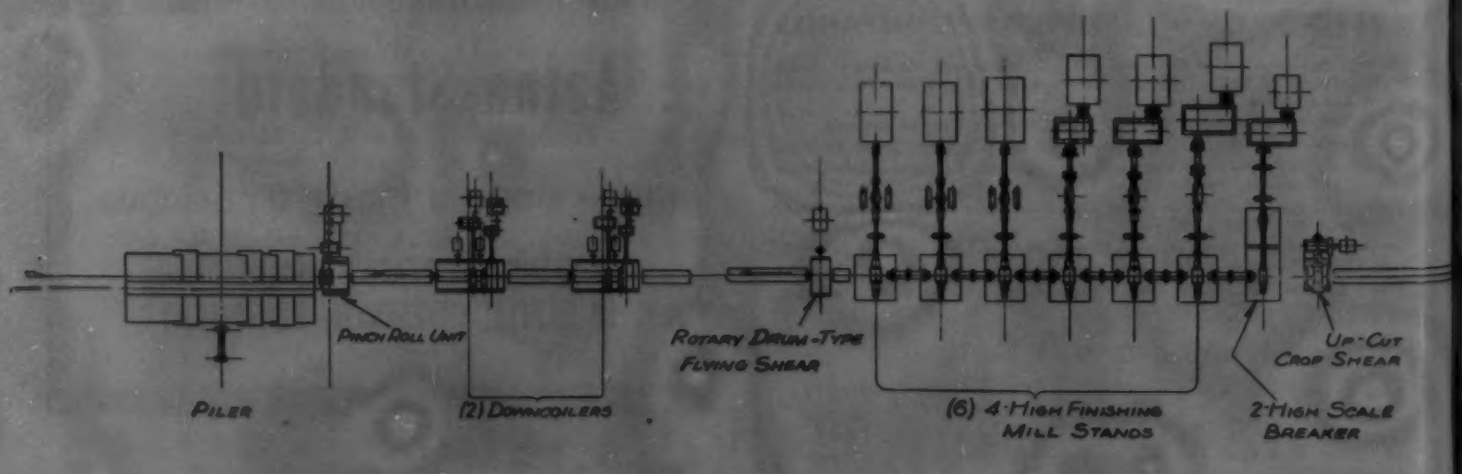
PLANTS IN WARREN, OHIO • ELLWOOD CITY, PENNSYLVANIA

51 YEARS OF CREATIVE ENGINEERING IN CAPITAL INVESTMENT EQUIPMENT

BLAW-KNOX

LEWIS CONTINUOUS

LEWIS PRODUCTS: Two-High Mills • Three-High Mills • Four-High Mills • Strip Mills • Bar, Billet and Structural Mills • Plate Mills • Rod Mills • Coilers • Tables • Shears • Pinion Stands • Gear Drives • Roll Lathes



produces hot rolled strip used in wide range of products

This versatile Lewis Continuous Hot Strip Mill is rolling out strip in a wide range of widths and gages . . . and of suitable chemical and physical properties to be used in a variety of products. These range from automotive parts, building hardware, household utensils, and cutlery to tin plate for packing food products.

Designed for straight line operation, from heating furnace to run-out tables, as shown in the drawing. Adapted for production of both cut sheets and coils. Two down coilers of completely new design produce a very tight and even coil.

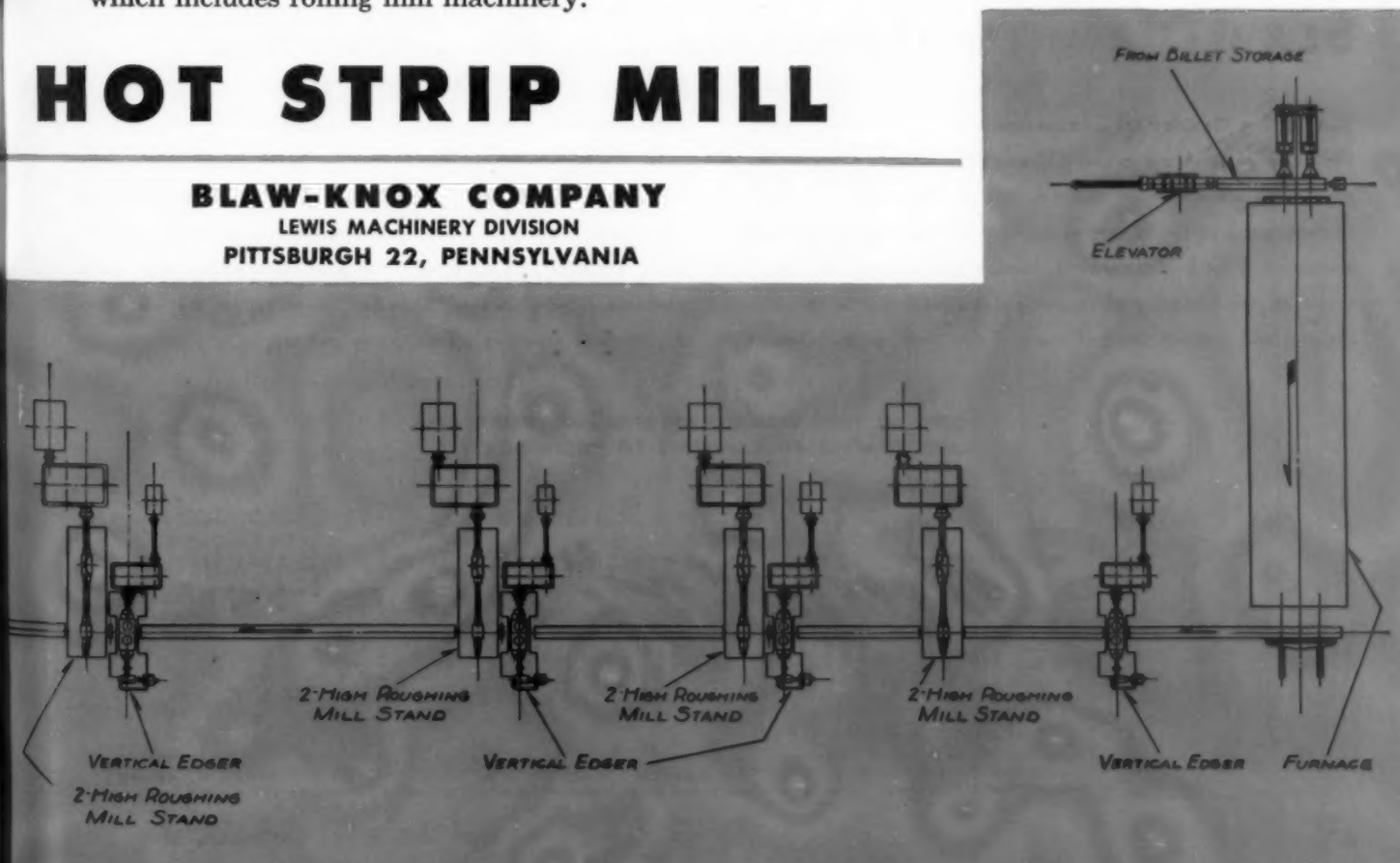
If increased production is desired in the future, a second furnace would readily double the present production. And an additional horizontal stand can be easily installed in space provided between No. 1 vertical edger and No. 1 horizontal stand.

The effective performance of the Lewis Continuous Hot Strip Mill is another example of how our engineers fully understand the most intimate details of mill practice. Their practical experience and engineering know-how enable them to design sturdy mill machinery to meet specific job requirements.

Our experienced engineering staff and modern manufacturing facilities are always readily available to help you with any problem which includes rolling mill machinery.

HOT STRIP MILL

BLAW-KNOX COMPANY
LEWIS MACHINERY DIVISION
PITTSBURGH 22, PENNSYLVANIA



SLAB TURNING GANTRIES . . . *by "Shaw-Box"*

Slab Turning Gantries are another specialty in the broad "Shaw-Box" Line of steel mill cranes. Numerous outstanding mechanical advantages are contained in them. Among these mechanical advantages are a perfected ratchet device that disengages the hoisting mechanism if the load is carelessly handled preventing trolley being raised off the bridge when engaging slabs; roller guides to guide the ram and prevent swing of mast; a ram that can be removed without disturbing the operating mechanism.

In "Shaw-Box" Slab Turning Gantries — whether built to an individual mill's or A.I.S.E. specifications — you get the added advantages that come from "Shaw-Box" engineering, fine workmanship, and precision manufacturing methods. These added advantages insure crane performance which makes "Shaw-Box" Gantries, for the work they do, the least expensive cranes to buy and use.

SEND ALL YOUR INQUIRIES FOR STEEL MILL CRANES AND SOAKING PIT CARRIAGES TO "SHAW-BOX"

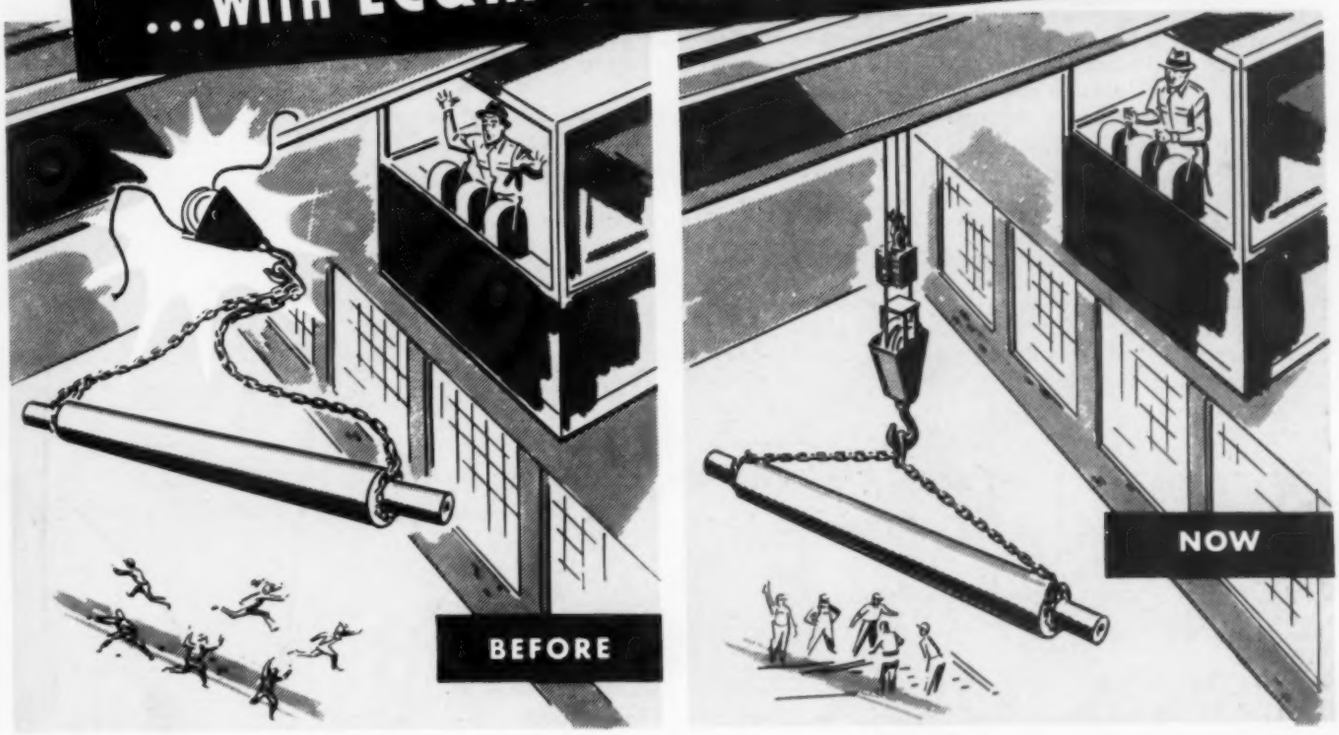
"Shaw-Box" CRANES

MANNING, MAXWELL & MOORE, INC.

Muskegon, Michigan

Builders of "Shaw-Box" Cranes, 'Budgit' and 'Load-Lifter' Hoists and other lifting specialties. Makers of 'Ashcroft' Gauges, 'Hancock' Valves, 'Consolidated' Safety and Relief Valves, 'American' Industrial Instruments and Aircraft Products.

FORGET OVERHOISTING DANGERS!
...WITH EC&M YOUNGSTOWN LIMIT STOPS

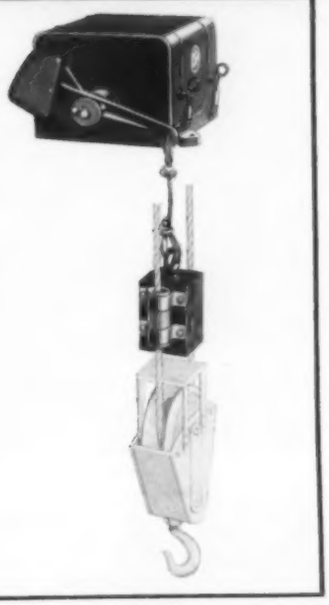


Now you can lift loads faster . . . with complete safety. Inexpensive safeguards against overhoisting accidents are EC&M Youngstown Safety Limit Stops which assure a quick, safe stop when the upper limit of travel is reached. The rising hook-block lifts the suspended-weight to operate these Limit Stops and disconnect power from the hoist motor. Should the hoist cables stretch, the tripping point doesn't change.

Easily installed on both a-c and d-c cranes, EC&M Youngstown Limit Stops remove fear of accidents from the operator's mind . . . enable him to work faster and surer . . . give him greater freedom to guide and handle loads with complete safety.

For dimensions and ratings, write today for factual Bulletin 1032

EVERY CRANE NEEDS THIS LIMIT STOP



YOU CAN LIFT LOADS HIGHER AND SAFER
WITH EC&M YOUNGSTOWN SAFETY LIMIT STOPS

1774

THE ELECTRIC CONTROLLER & MFG. CO.
2698 East 79th Street · Cleveland 4, Ohio

Slits, coils 1/8" steel at high speeds

. . . with cutters on TIMKEN® bearings

STEEL of ⅛-inch thickness is slit and coiled at high speeds by this Stamco 60" Coil Slitter. To carry the heavy loads and to keep the cutters aligned, Stamco mounts the cutter arbors on Timken® tapered roller bearings. And to assure a smooth, even transmission of power, all gear reduction units are mounted on Timken bearings.

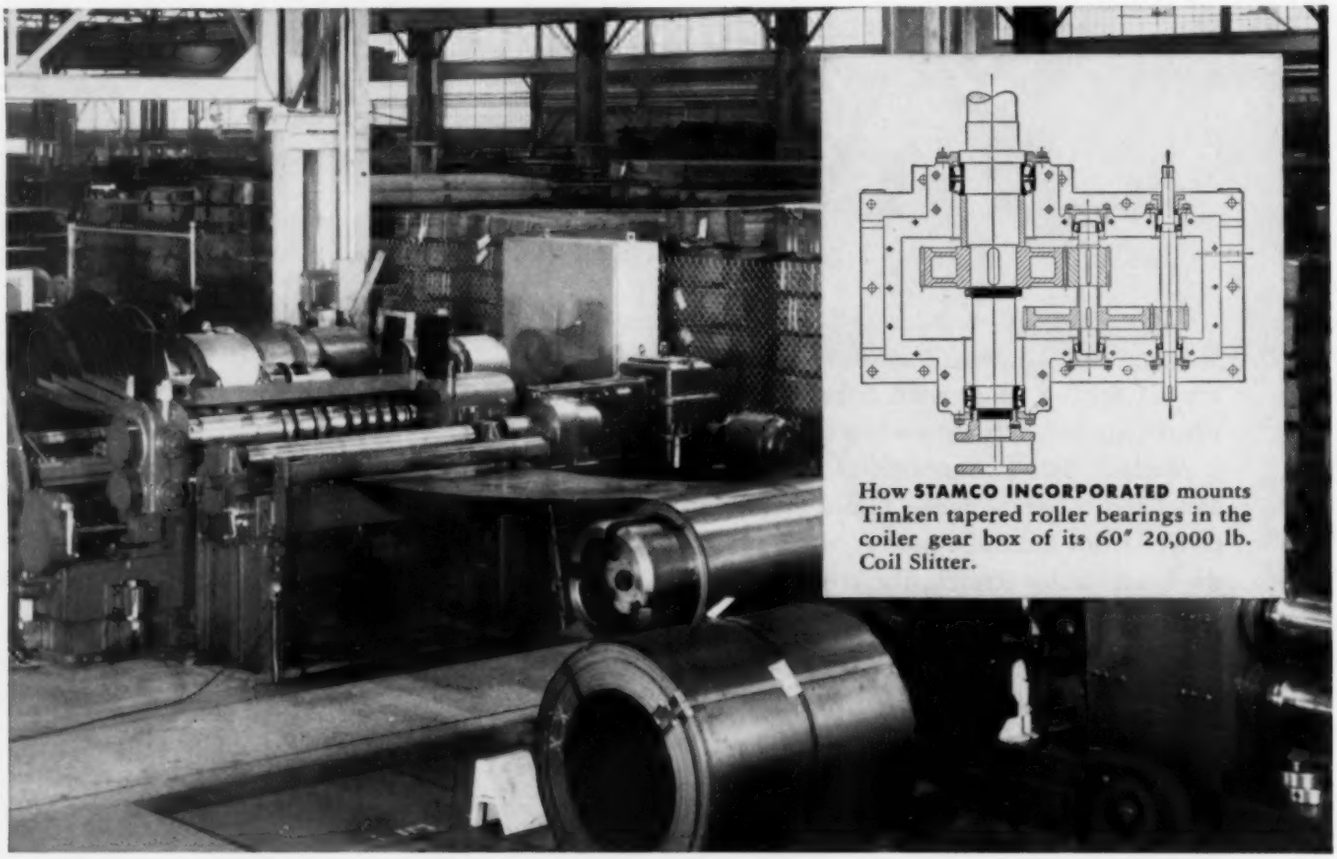
Line contact between the rollers and races of Timken bearings gives them extra-carrying capacity. And their tapered design enables them to take both radial and thrust loads in any combination. Cutter arbors are kept in positive alignment, insuring precise slitting even at high speeds (on light-gauge steel up to 2,200 feet per minute).

Because reducer shafts are also held in rigid alignment, gears mesh accurately to give a smooth flow of power, less gear wear, less maintenance. Power loss is further reduced because the true rolling motion and smooth surface finish of Timken bearings make friction negligible.

These bearings are made of the finest steel ever developed for bearings—Timken fine alloy steel. We have to make it ourselves because that is the only way we can get steel good enough for Timken bearings. They normally last the life of the coil slitter.

No other bearing gives you all the advantages you get with Timken bearings. Specify them for all the machines you build or buy. Look for the "Timken" trade-mark on every bearing. The Timken Roller Bearing Company, Canton 6, Ohio. Canadian plant: St. Thomas, Ontario. Cable address: "TIMROSCO".

This symbol on a product means its bearings are the best.



How **STAMCO INCORPORATED** mounts Timken tapered roller bearings in the coiler gear box of its 60" 20,000 lb. Coil Slitter.

FINISHED TO CLOSER TOLERANCES

Finishing to incredible smoothness accounts for much of the precise, smooth rolling performance of Timken bearings. This honing operation is typical of the amazingly accurate manufacturing methods at the Timken Company.

The Timken Company is the acknowledged leader in: 1. advanced design; 2. precision manufacturing; 3. rigid quality control; 4. special analysis steels.

TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS

NOT JUST A BALL ○ NOT JUST A ROLLER ⬭ THE TIMKEN TAPERED ROLLER ⬭ BEARING TAKES RADIAL ↓ AND THRUST →○← LOADS OR ANY COMBINATION →○←

CONTINENTAL

CONTINUOUS BILLET and BAR MILL

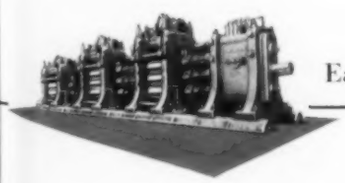
Modernize to Economize

If obsolete mills are cutting your profits or pricing you out of your market, modernize to economize. Take advantage of Continental's experience with ferrous and non-ferrous rolling mills. You can have any type designed, built and installed—with complete auxiliaries—under a single responsibility.

CASTINGS—carbon and alloy steel from 25 to 300,000 pounds.

ROLLS—iron, alloy iron and steel rolls for all types of rolling mills.

WELDMENTS—fabricated steel plate, or cast-weld design.



Plants at
East Chicago, Ind. • Wheeling, W. Va. • Pittsburgh, Pa.

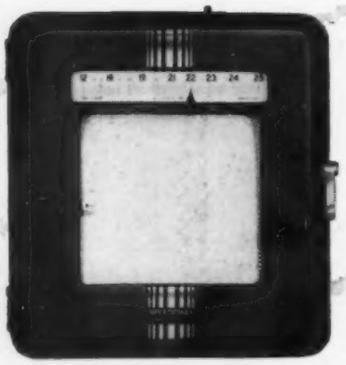
CHICAGO • PITTSBURGH

CONTINENTAL
Foundry & Machine
Company

For highest OH air-preheat...

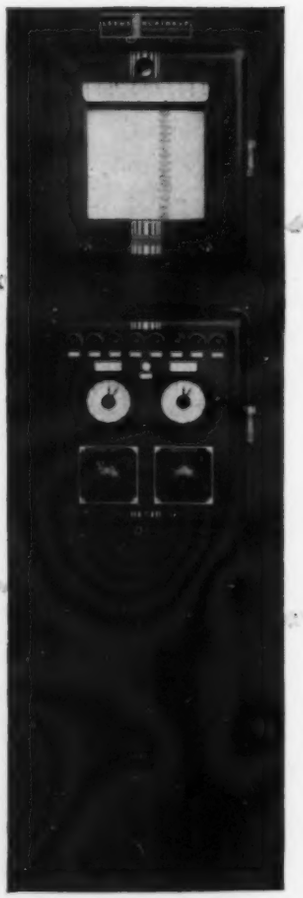
L&N OFFERS YOU 3 INSTRUMENTATION PROGRAMS

Efficient operation of regenerative furnaces demands reliable instrumentation, to assure balanced reversal of firing for highest average air-preheat. To suit your specific preferences, L&N offers a choice of equipment which can be readily adapted to your present installation.



1. If you require a reliable indication and record of checker temperatures only, as a guide to manual reversals, the strip-chart Model S Speedomax recorder measures two, four, or six temperature points, detected by thermocouples or Rayotube (radiation-type) detectors sighting directly on the brick.

2. If you require automatic reversal of firing on the basis of time alone, the L&N Master Reversal Control Unit compactly houses all essential elements in one case—timers, signal lights, relays, and switches to select automatic or manual operation.



3. If you require a completely flexible system, the Master Reversal Control Unit combined with a Speedomax Temperature-Temperature Difference Recorder-Controller offers a choice of automatic reversal based on time, temperature difference, or temperature difference *or* time, as well as manual reversal.

The Speedomax instrument charts a continuous two-point record of checker temperatures—detected by thermocouples or Rayotube detectors—and can initiate reversal on the basis of pre-set temperature difference . . . functions which normally require *two* conventional instruments.

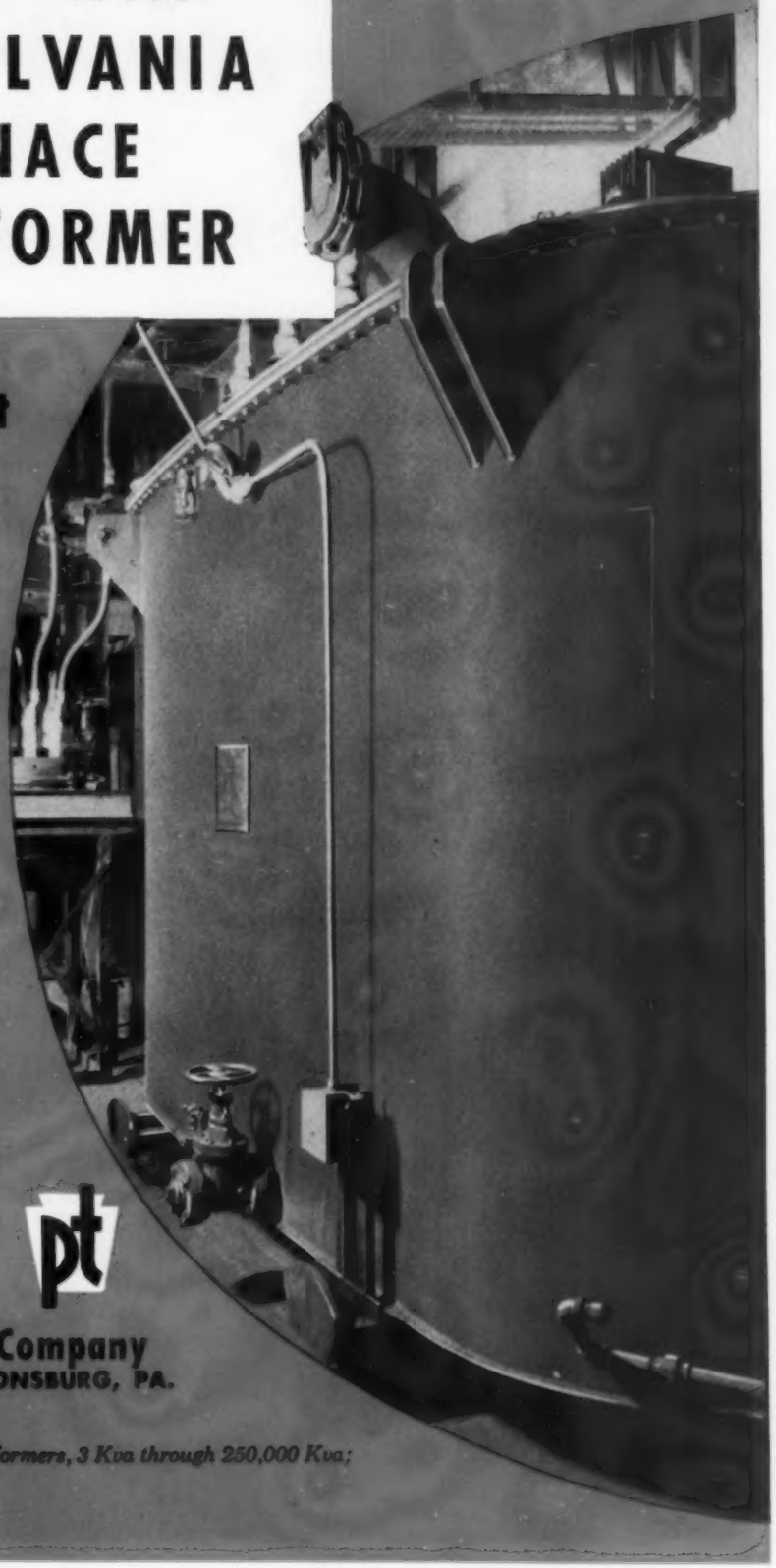
Full details of this equipment are available on request. Simply contact our nearest office, or write us at 4942 Stenton Ave., Philadelphia 44, Pa.

LEEDS NORTHRUP
Instruments — *automatic controls • furnaces*

Jrl. Ad. N-33-640(6)

New Jersey Zinc uses this

6,000 KVA PENNSYLVANIA FURNACE TRANSFORMER



at its Palmerton Plant

Pennsylvania Transformer Company has manufactured well over 1¼ million Kva of furnace transformers in ratings from 100 Kva through 25,000 Kva. The 6,000 Kva transformer at Palmerton is one of five furnace transformers purchased from Pennsylvania by New Jersey Zinc Company (of Pa.).

The successful operation of all Pennsylvania furnace transformers and their industry-wide acceptance indicate that Pennsylvania engineers fully understand the application of furnace transformers to electric furnaces.

The complicated design of a furnace transformer presents many problems that do not apply to other types of transformers. Many special conditions, such as overloads, short circuit stresses, distribution of currents, and reduction of losses must be met by engineering skill and highly perfected workmanship. Pennsylvania Transformer Company combines this engineering "know-how" and expert workmanship into each and every furnace transformer.

Pennsylvania Transformer Company

A McGraw Electric Company Division • **CANONSBURG, PA.**

Greater Pittsburgh District

Manufacturers of Power and Distribution Transformers, 3 Kva through 250,000 Kva; 480 volts through 330,000 volts.

CONTINUOUS STRIP ANNEALING in DREVER VERTICAL FURNACES

Saves Time • Reduces Cost

Outstanding PRODUCT

A Uniformly annealed strip from edge to edge and end to end of coil

B Uniform Physicals throughout the coil

C Clean, Lustrous Surface that electro-tins uniformly

D Stickers and "Dog Ears" eliminated

E Users of Continuous Annealed Strip report longer die and shear life

Drever Company has pioneered this striking improvement in Continuous Annealing Furnaces for Tin Plate Strip, Silicon Strip, Blue Plate and other strip products. We predict all major steel mills will anneal by this method. Why don't *you* do it now?

Equipment can be specified for output up to 30 tons per hour of 30″ wide x .010″ thick low carbon steel. Several sizes are available, in any width.

Furnace illustrated produces Tin Plate and Blue Plate. The shift-over from the Bright Surface required for Tin Plate to the uniformly applied, accurately controlled tight oxide coating required for blue plate is rapidly and easily made.

Installations backed by staff of Engineers and Metallurgists of sixteen years experience in Continuous Annealing of Low Carbon Strip.

Outstanding DESIGN

1 Speeds up to 1000 feet per minute

2 Controlled Strip Tension, excellent tracking

3 Controlled Heating and Soaking Time

4 Regulated Cooling Rate

5 Predictable Strip Temper

6 Cleaning in same line

7 Low Maintenance

8 Reduction in Floor Space

9 Reduction in Coil Inventory

10 Overall Saving in Annealing and Cleaning Costs

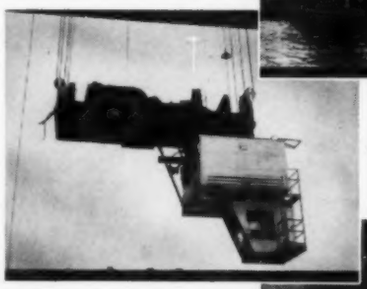
DREVER CO.
730 E. VENANGO ST.
PHILADELPHIA 34, PA.

12-ton ore bridge, built, designed and installed for a large steel company.

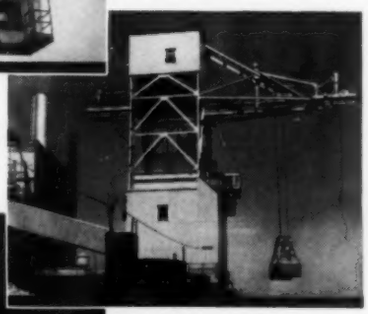
DRAVO HEAVY MATERIALS-HANDLING EQUIPMENT ...CUSTOM BUILT FOR YOU!

Travelling unloading towers built to handle imported iron ore at an Atlantic port.

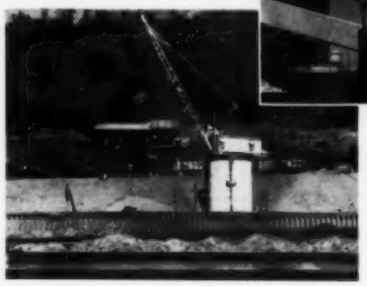
Whirler crane mounted on pontoon hull is used for dredging and general contract work.



Light-weight man trolley installation increased bridge handling capacity 60%.



Coal unloader designed and built for a large mid-western electric power company.



Stationary whirler crane designed and built to transfer coal from barges to hopper cars.

Over-all economical and safe performance is best obtained by using materials-handling equipment designed to suit your operating conditions. If you're planning a new materials-handling installation, we suggest an early "Round Table" session with Dravo engineers.

From actual experience over the past 60 years in building and installing the equipment shown here, valuable data is available in working out the features you want in your installation. This information, along with your own operating experience, can be used to create a design incorporating all the best features for easy maintenance, a high safety factor and simple, economical and satisfactory operation.

You can profit by taking advantage of this specialized "Round Table" service.

DRAVO

CORPORATION

NEVILLE ISLAND, PITTSBURGH 25, PENNSYLVANIA

AIR CONDITIONING • BOILER AND POWER PLANTS
CRANE CAB COOLERS • DOCKS • INDUSTRIAL FOUNDATIONS
OPEN STEEL FLOORING • PUMP HOUSES AND INTAKES
SPACE HEATERS • WATER AND WASTE TREATMENT PLANTS
TOWBOATS AND BARGES

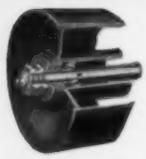
7 solid reasons why it pays to standardize on LINK-BELT IDLERS

1 STRONG, RIGID FRAMES support rolls in perfect alignment. Rolls are securely held in place but can be easily removed for inspection and service.

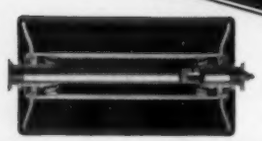
2 CONCENTRIC ROLLS have smooth surfaces and rounded edges. Machine-made, continuous welds prevent entrance of dirt and moisture—assure hop-free rotation.

3 HUSKY, HIGHEST QUALITY BEARINGS, free and easy turning, provide concentricity and perfect alignment for smooth operation, minimum belt wear, low power requirements.

4 SAFE, CONVENIENT GREASE FITTINGS provide ease of lubrication. Extensions can be furnished for greater accessibility in out-of-the-way locations.



5 POSITIVE, COMBINATION GREASE SEAL unit retains lubricant, prolongs bearing life. The most effective seal offered in idlers today!



6 ROLLS consist of a counterbored outer shell plus a full-length, heavy central tube of 3/16-in. steel. Both tube and shell are welded to dished steel heads to maintain balance and bearing alignment.

7 HEX NUTS provide bearing adjustment at shaft ends and prevent rotation in service. Nuts prevent bracket from spreading under unusual impact.

Get the right idler from industry's most comprehensive line

Link-Belt makes more than 500 belt conveyor idlers in 34 types. You can select from light, medium or heavy-duty 20° troughing idlers, two types of 45° idlers, flat belt, belt training, rubber cushion and the new Link-Belt variable troughing idler. Most are built in a broad range of roll diameters and belt widths with matching return idlers. Ask your Link-Belt sales representative or distributor for new 48-page Book 2416.

LINK-BELT

BELT CONVEYOR IDLERS

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office: New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 19,419

CONTROLLED SPEED—

A DISTINCTIVE FEATURE OF ALL-

Vaughn® MOTOBLOX®

The speed of each block is AUTOMATICALLY controlled to meet the preset speed of the finishing block—thereby eliminating SLIP and accumulation of wire on intermediate blocks.

The Vaughn MOTOBLOX is a truly non-slip machine – check the facts with a Vaughn engineer!

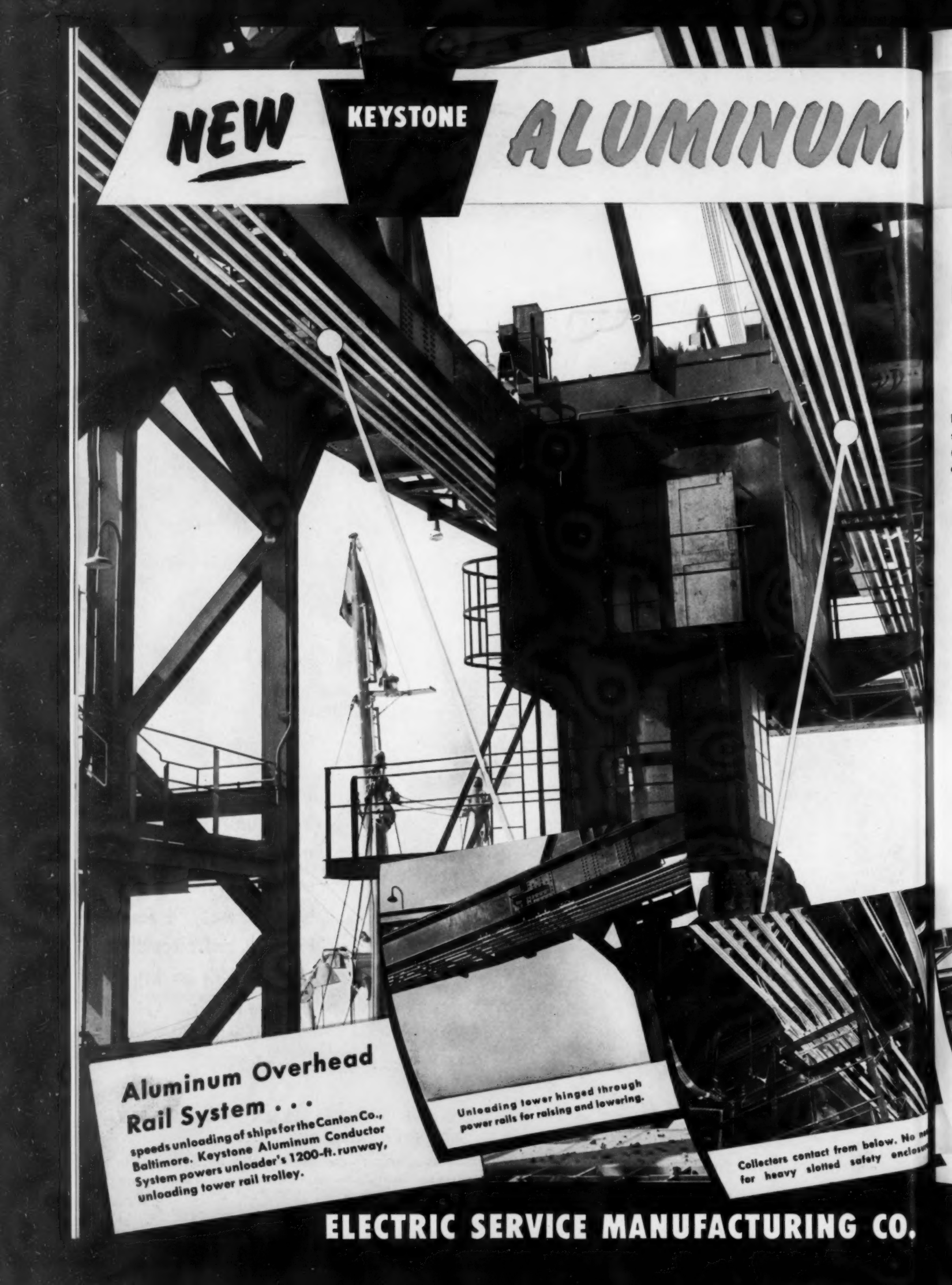
"Quick on the Draw!"

THE VAUGHN MACHINERY COMPANY

CUYAHOGA FALLS, OHIO, U. S. A.

COMPLETE COLD DRAWING EQUIPMENT—Continuous or Single Hole . . . for the Largest Bars and Tubes . . . for the Smallest Wire . . . Ferrous, Non-Ferrous Materials or their Alloys.

NEW KEYSTONE ALUMINUM



Aluminum Overhead Rail System . . .

speeds unloading of ships for the Canton Co., Baltimore. Keystone Aluminum Conductor System powers unloader's 1200-ft. runway, unloading tower rail trolley.

Unloading tower hinged through power rails for raising and lowering.

Collectors contact from below. No ne for heavy slotted safety enclosu

ELECTRIC SERVICE MANUFACTURING CO.

CONDUCTOR SYSTEM

PROVED 7 WAYS BETTER THAN THE STEEL THIRD RAIL SYSTEM

Here's why it paid the Canton Company of Baltimore to switch from conventional conductors to Keystone Aluminum throughout for their new high-speed ore unloader and 1200-foot-long 2300-volt main runway.

1 CORROSION REDUCED

Salty dampness doesn't faze the Keystone Aluminum System. Cleaner contact surfaces protected from dirt and damage.

2 LOW VOLTAGE DROP

The non-magnetic qualities of the Keystone Aluminum System increase current capacity through lower reactance and close conductor spacings.

3 GREATER CAPACITY

1000 amp rating provides capacity for additional equipment without boosters or multi-point feeds.

4 SENSITIVE CONTROL

Corrosion resistant Keystone Aluminum Systems assure positive contact on most sensitive control circuits.

5 DEADWEIGHT SLASHED

Lighter than steel. Needs no heavy supporting structure. Compact 2300-volt runway safely protected with standard enclosure.

6 LONGER COMPONENT LIFE

Multiple contact collectors prevent arcing and heating. Less vibrating weight saves insulators. Smooth, clean contact surfaces and low current densities mean longer shoe life.

7 INSTALLATION EASED

Compact design, pre-fabricated, lightweight units mean lower labor and installation costs for either open or closed systems.

Could you use this modern system NOW to obtain efficient operation in your construction or improvement program? Write for complete data today on our Keystone Aluminum Conductor System. Our engineers are ready to help you in either the Keystone Aluminum System or the conventional copper or steel system.

Head-on view of traveling crane: unloading tower in position, control car retracted.

Small insulators made feasible through compact, lightweight aluminum system.

Philadelphia 32, Pa.

Represented in Canada by Lyman Tube and Bearings, Ltd., Montreal and Toronto

The instrument that put electronics to work

Before electronics came into the picture, industrial instrumentation was caught in a squeeze. On one hand, it was besieged with demands by production men and engineers for higher sensitivity, faster speeds, and greater reliability. And on the other hand, it was hampered by the limitations of mechanical devices. For the instruments of fourteen years ago were merely mechanical imitations of a man watching a galvanometer needle and twiddling dials. They were too delicate . . . too sensitive to vibration . . . too easily led astray by wear or maladjustment. They just couldn't deliver the performance that new production methods required.

In 1940, however, came a major milestone in the progress of instrumentation—development of the *ElectroniK* potentiometer. This was not only a new kind of instrument. It was a new concept of measurement. For the first time, it applied the science of electronics in a practical way to the design of a measuring device for industry. It replaced complicated, fragile mechanical gadgets with a simple but sensitive electronic circuit and servo system . . . the "Continuous Balance" principle of measurement.

You could tell it was something new when you opened up the *ElectroniK* instrument's case. There was no sign of whirring gears, levers and cams. You could tell it was giving a new kind of performance in measurement, too, by the way the pointer would move swiftly and surely in one smooth sweep whenever the measured variable changed.

The *ElectroniK* instrument gained quick acceptance by production men, engineers, research technicians and maintenance men. They liked the way it provided laboratory accuracy and sensitivity, week after week, under the toughest industrial service conditions. They found that its speed and precision made possible improvements in product quality and process operation that had been unattainable before. And they have proved their confidence by ordering and reordering *ElectroniK* instruments by the thousands . . . not solely because it was *first* of its kind, but because it has continued to be the *best* in performance.

ElectroniK

control of Btu input boosts

Flow meter body (arrow) measures gas flow; Honeywell diaphragm operator on butterfly valve throttles input as directed by the ElectroniK instrument.

Fuel input to these 200-ton open hearths at TC&I's Fairfield Steel Works, near Birmingham, Alabama, is automatically controlled by ***ElectroniK*** *instruments. Small picture shows one of the fuel control systems, consisting of two* ***ElectroniK*** *integrating controllers.*

open hearth efficiency

AUTOMATIC CONTROL of heat input to open hearth furnaces, by means of *ElectroniK* flow instrumentation, is helping to effect important improvements in production and economy at the Tennessee Coal & Iron Division of United States Steel Corporation. By giving the first helper fingertip control over Btu's, TC&I not only makes efficient use of fuel, but also improves steel output by increasing the length of furnace campaigns.

The fuel control system for each 200-ton furnace is designed to accommodate any of four different fuels. One *ElectroniK* instrument is used when firing coke oven gas or natural gas; its double scale is calibrated directly in Btu's per hour for both types of gas. The second instrument is used in conjunction with fuel oil or tar. Each instrument indicates and records flow continuously . . . accurately adds up total flow on a counter-type integrator . . . and automatically positions a control valve in the corresponding fuel line to hold flow at any value designated.

Without leaving the panelboard, the first helper can check the fuel rate at any instant . . . can quickly shift fuel flow to whatever input is required to keep the furnace at proper temperature. At the end of the heat, he has a complete record of furnace input and a precise measurement of Btu's supplied.

ElectroniK instrumentation can probably help your own mill operations in dozens of ways. For a discussion of your specific requirements, call your nearby Honeywell sales engineer . . . and he's as near as your phone.

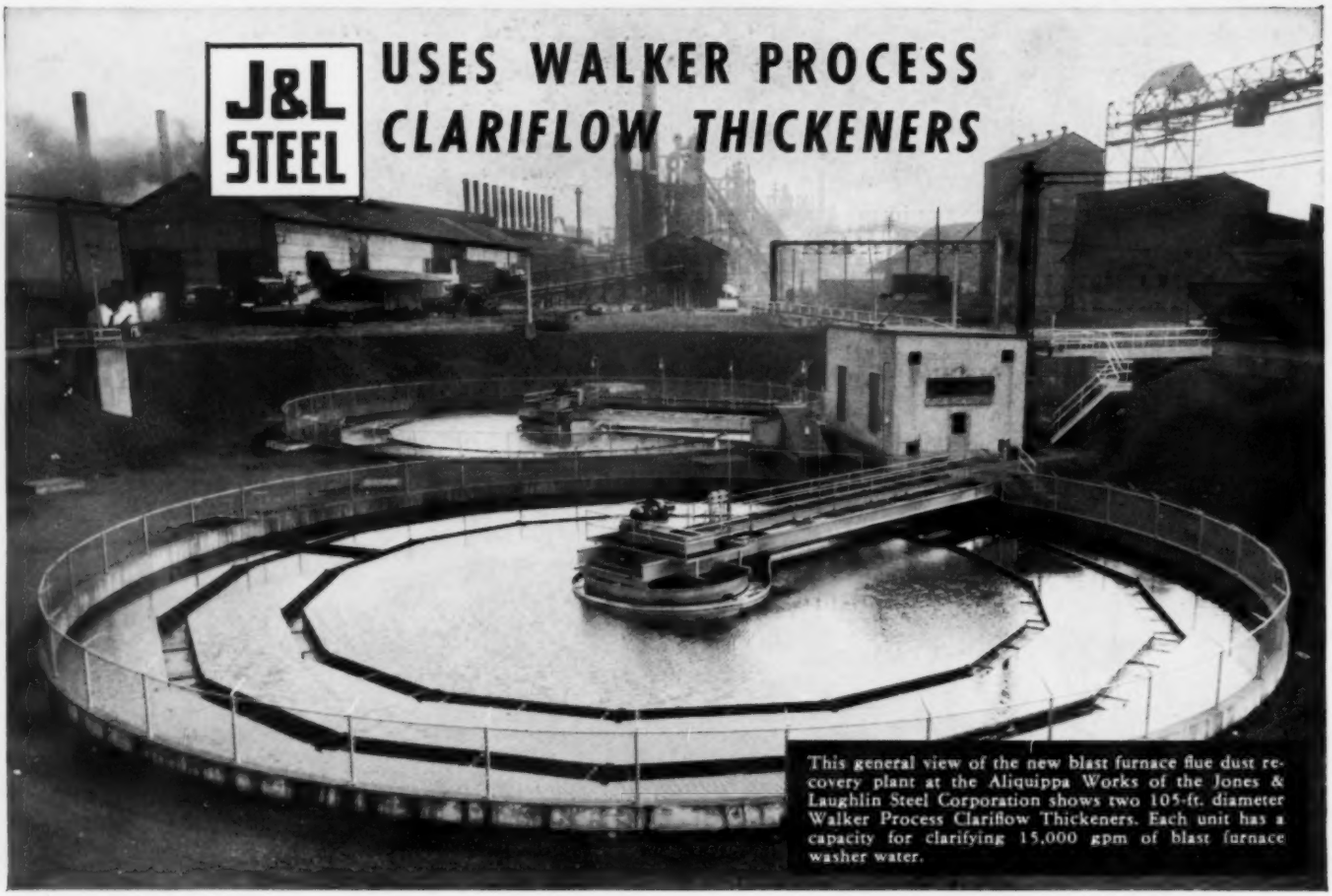
MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

● **REFERENCE DATA: Write for Catalog 1531, "*ElectroniK* Controllers"... and for Data Sheet No. 6.4-11, "Faster Heat-up for High Temperature Furnaces."**

MINNEAPOLIS **Honeywell**

BROWN INSTRUMENTS

First in Controls



This general view of the new blast furnace flue dust recovery plant at the Aliquippa Works of the Jones & Laughlin Steel Corporation shows two 105-ft. diameter Walker Process Clariflow Thickeners. Each unit has a capacity for clarifying 15,000 gpm of blast furnace washer water.

NEW BLAST FURNACE FLUE DUST RECOVERY PLANT

Removes Over 95% of Settleable Solids!

Single stage thickeners used

Two single stage Clariflow Thickeners were used in the Jones & Laughlin Steel Corporation Aliquippa Works for the following three jobs: (1) to remove over 95% of the settleable solids, (2) clarify the flow to less than five grains and (3) to thicken "mud" to within 40-50% for filtration.

Thickeners have inlet diffusers

The Clariflow Thickener is constructed for rugged use and is capable of overloading without work stoppage. It is provided with a multiple tangential inlet diffuser so that the flow of material entering the unit is uniformly diffused in a rotating manner.

"Short circuiting" at inlet prevented

Balanced rotation at the inlet of the Clariflow Thickener prevents short circuiting and the multiple weir troughs spaced over the entire rise area insure uniform slow rise to the surface of the water being clarified. This assures a clarified overflow containing the least amount of solids.

WRITE FOR BULLETIN 10169

WALKER PROCESS

CLARIFLOW
thickeners

WALKER PROCESS WALKER PROCESS EQUIPMENT INC.
FACTORY • ENGINEERING OFFICES • LABORATORIES
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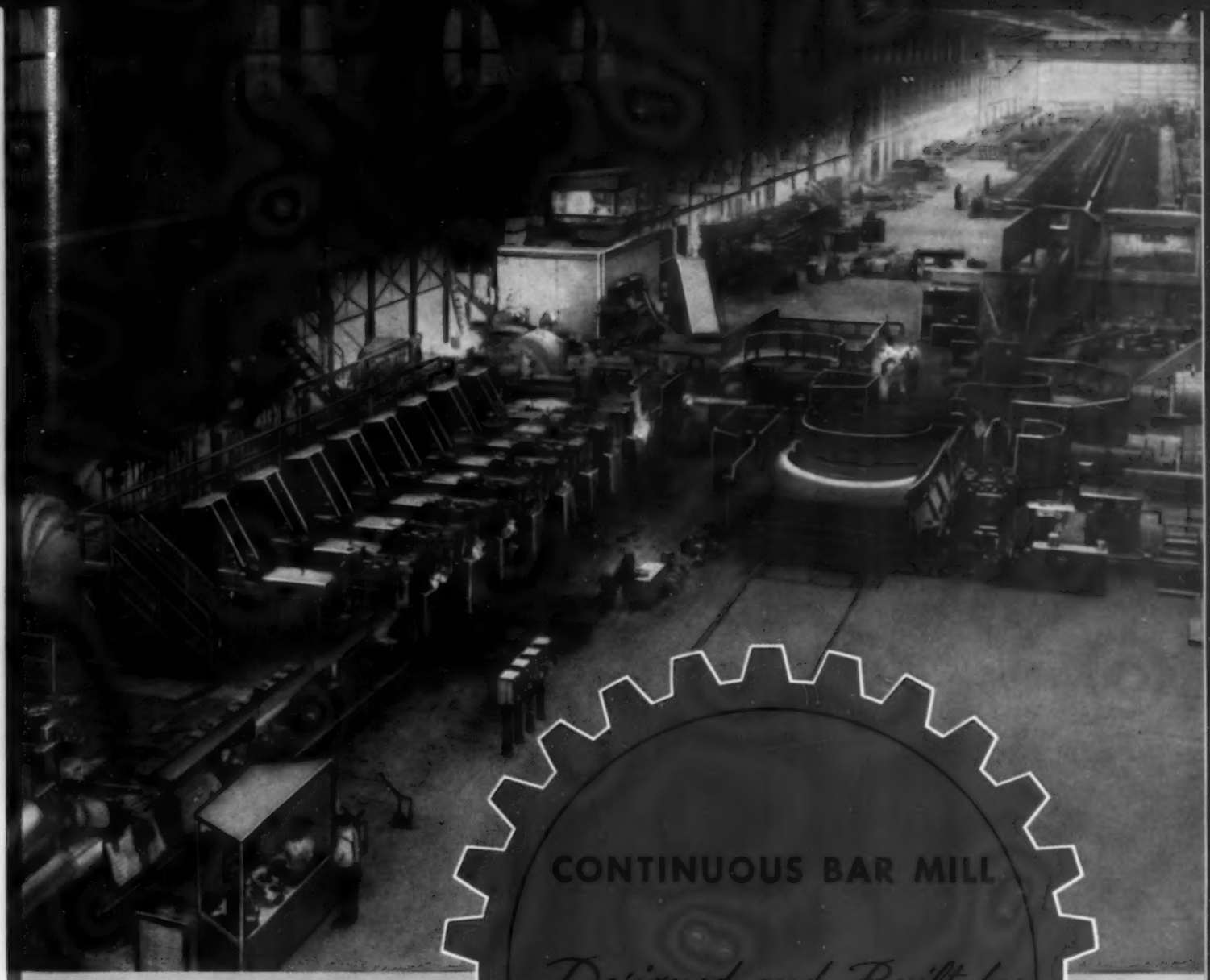

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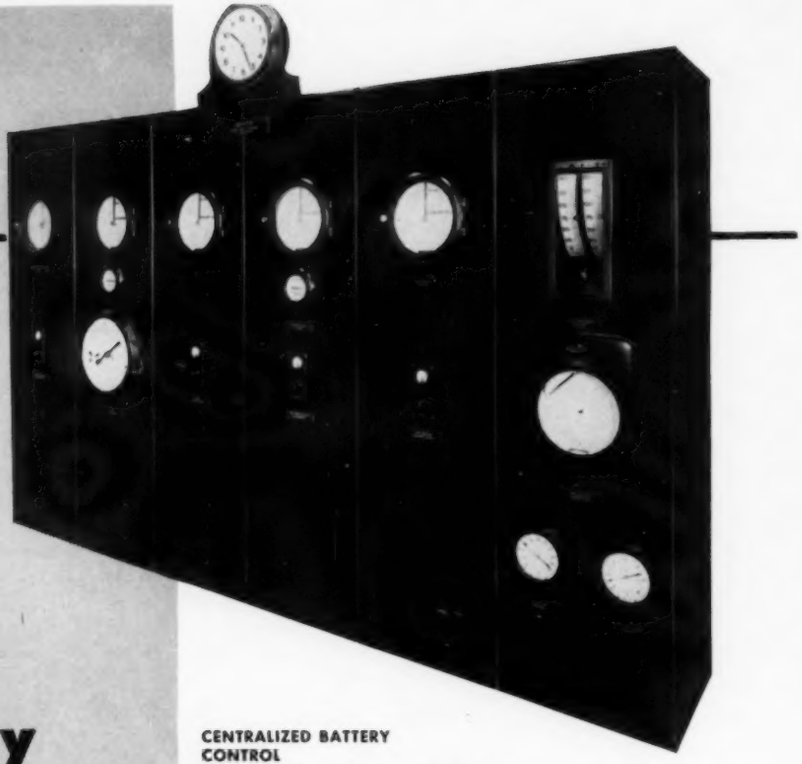
Newest

REPUBLIC CONTROLS installed on coke battery



CENTRALIZED BATTERY CONTROL
at this panel permits an operator to coordinate automatic regulators controlling stack draft, fuel gas volume and pressure and blast furnace gas pressure. Gages and regulators monitor the system.

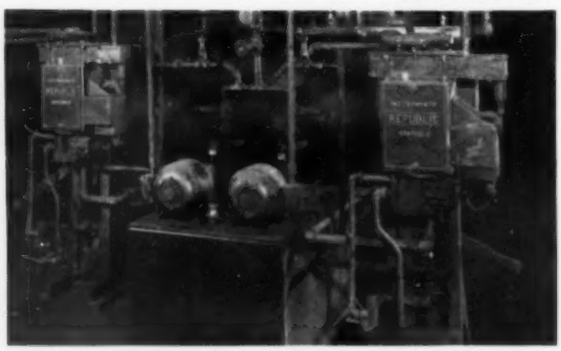
When a new coke battery was added to the coke plant of a mid-western steel mill, Republic electrically controlled hydraulic regulators were installed to control the additional capacity. These new type regulators supplement Republic-Smoot regulators which have been in operation on some of the older batteries for more than 34 years. Dependability, the determining factor in the selection of the new equipment, was more than proven by the performance of the older controls.

The same features—ruggedness and simplicity—which kept these controls in continuous service year after year are embodied in modern Republic Instruments and Controls. That's why Republic equipment remains dependable, regardless of dirt, heat, shocks and vibration. It's also why steel mills such as this one specify Republic, again and again.

GET ALL THE FACTS ABOUT REPUBLIC INSTRUMENTS AND CONTROLS FOR STEEL MILLS

- **ELECTRIC FLOW METERS** for continuous integration and fast transmission of flow information
- **PNEUMATIC ELECTRIC FLOW METERS** for oxygen scarfing and dirty gases
- **LOW PRESSURE RECORDERS** for open hearths, soaking pits, coke ovens, reheating furnaces, smelting furnaces
- **HIGH SPEED POSITIONING OPERATOR** for furnace doors
- **FURNACE PRESSURE REGULATORS**
- **FLOW REGULATORS**
- **BTU TOTALIZERS** for more efficient operation of open hearth furnaces

Write for literature on any of the above



ELECTRICALLY CONTROLLED REGULATORS. The control point of these Republic hydraulic type regulators is set electrically from control panel. In case of failure of hydraulic system, oil trapping valve will lock the regulators in their last position before failure. Electrical failure or accidental shorting of the transmission lines will not cause regulators to shift their control setting.

STILL IN SERVICE AFTER 34 YEARS. These old type Republic-Smoot regulators were installed in 1919 when the coke batteries were built. They operate on the force-balance principle, which permits strong, durable construction without loss of accuracy or sensitivity. This same operating principle is used in modern Republic regulators and pneumatic transmitters.

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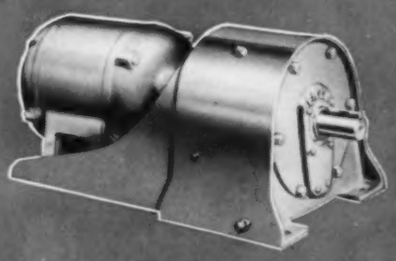
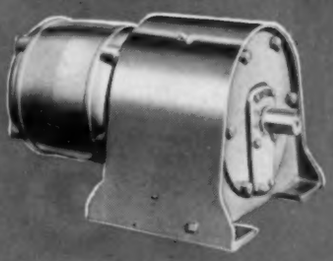
many types, sizes, styles, arrangements...

ALL-STEEL FALK Motoreducers

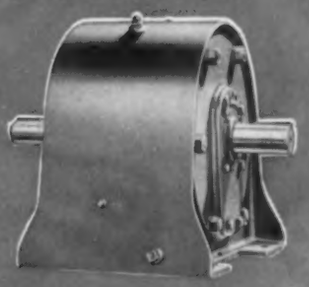
cover the entire application range



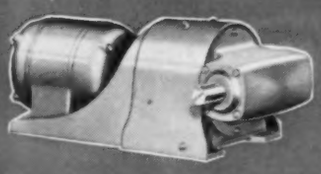
Type EZ, All-Motor Horizontal Motoreducer. Accommodates any make or type of foot-mounted motor.



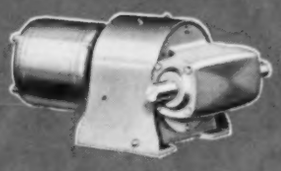
Type EF, Integral Horizontal Motoreducer. Standard NEMA D-flange motor mounts directly on Motoreducer housing.



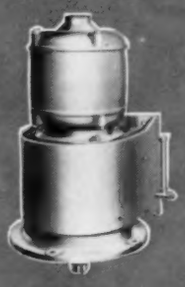
Type EC, Concentric Shaft Speed Reducer. Coupling, chain or belt driven.



Type EBZ, All-Motor Right Angle Motoreducer. Any output shaft position (see below, right).



Type EBF, Integral Right Angle Motoreducer. Employs NEMA D-flange motor.



Type EFX, Integral Vertical Motoreducer. Employs NEMA D-flange motor.

Type EZX, All-Motor Concentric Motoreducer. For vertical applications.

Type ECB, Right Angle Speed Reducer. Any output shaft position; coupling, chain or belt driven.

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The name FALK on a reducing unit of any size or type is your positive guarantee of highest quality, value and efficient performance with minimum maintenance throughout its long life.

All-steel FALK Motoreducers—both the All-Motor and Integral types—are available in horizontal and vertical models with double, triple or quadruple reduction; concentric and right-angle shaft arrangements. They cover a surprisingly wide range in horsepowers and in output speeds. Every FALK Motoreducer is built and rated according to AGMA standards.

Whatever your reduction requirements—be they simple, complex or "different"— it is just good business to consult FALK, recognized leader in the Motoreducer and speed reducer field. Write to Department 247.

Every FALK Motoreducer has these "IN-BUILT" Factors

All-steel Housings. Unbreakable, strong, rigid. Generous overhung load capacities provided by wide bearing spans, large shafts and bearings.

Precision Gearing. Heat-treated alloy steel, precision cut and shaved helical gearing throughout . . . quiet-operating crown shaved pinions . . . taper bored gears for easy ratio changes.

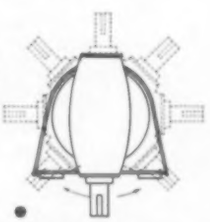
Sealed Housings. Dual closures and one-way vents keep oil in, dust and moisture out. Units are splashproof, leakproof, dustproof.

Wide Speed Range. Selective ratio combinations provide output speeds from 1.5 rpm to 1430 rpm with stock gears.

Streamlined inside and outside. Smooth, clean surfaces; machine welded construction conforms to NEMA motor frames.

Positive Lubrication. Large sump capacity . . . oil-tight construction assures clean lubricant . . . direct dip of revolving elements provides positive lubrication at all speeds.

Any Output Shaft Arrangement (on Right Angle models). Shafts can be furnished in horizontal, vertical or angle position as shown in sketch at right.



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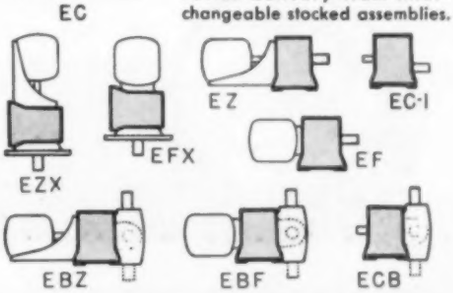
The basic E design permits maximum use of standardized parts . . . closer control over materials, processing, inspection and assembly . . . resulting in faster delivery from interchangeable stocked assemblies.

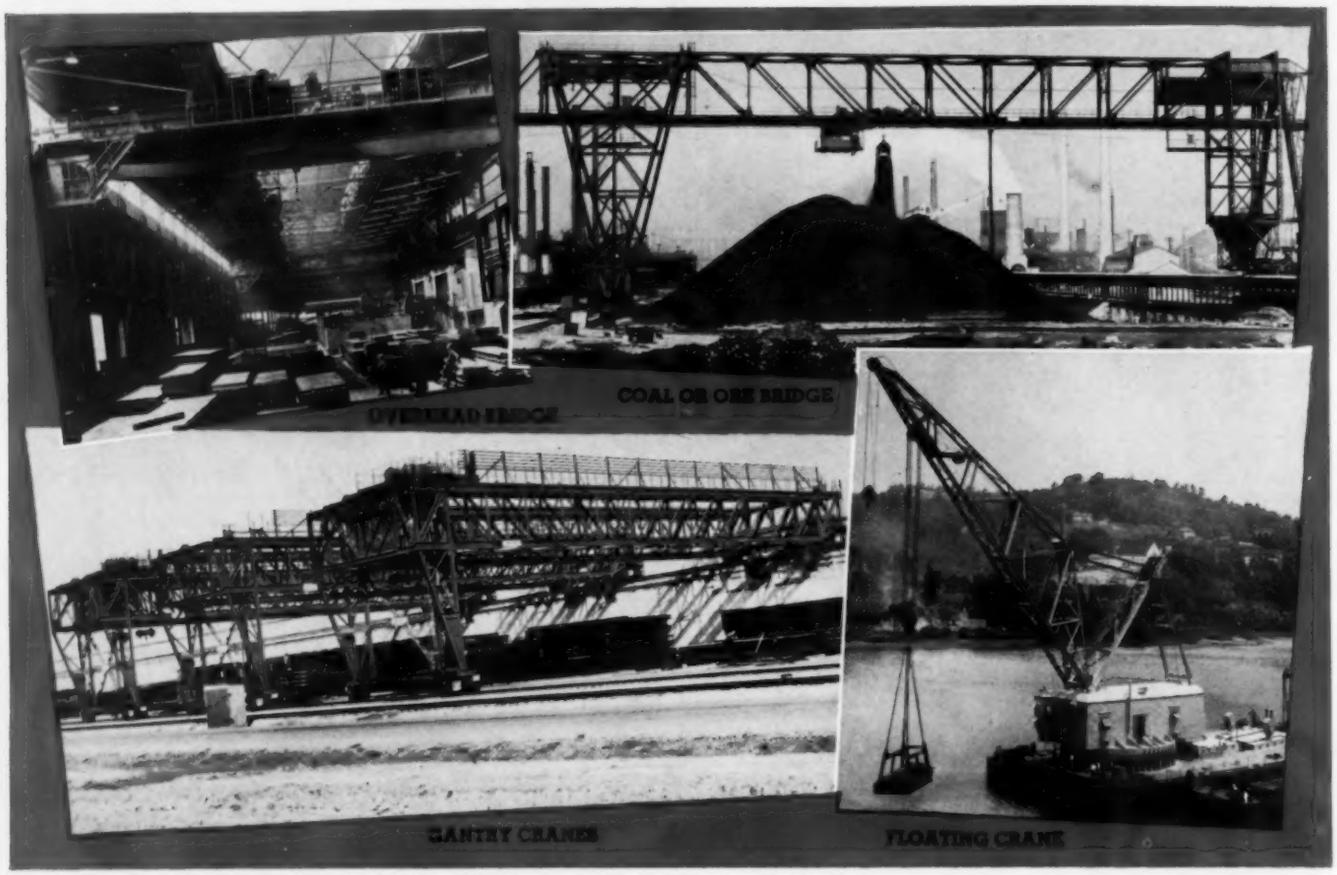


FALK ...a good name in industry

THE FALK CORPORATION, 3001 W. Canal St., Milwaukee 8, Wis.

WRITE TO DEPARTMENT 247

CLARK CRANE CONTROLS



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• GREATER SAFETY — *for any type of crane*

Of the many outstanding performance, maintenance and safety features built into CLARK Crane Controls, three are especially important:

1. The VARI-TIME PRINCIPLE. Smooth, rapid "definite-time" acceleration is achieved by the famous CLARK VARI-TIME core, guaranteed trouble-free for the life of the equipment. This is built as an integral part of the "RT" contactor for the ultimate in simplicity, or furnished with the "VT" relay—a relay built like a contactor. It greatly simplifies the circuits.
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Many additional features contribute to fast, dependable performance and consistent, trouble-free service.

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Typical CLARK Crane Hoist Control Panel.

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Patent Reviews

By MELVIN NORD
Patent Attorney
Detroit, Mich.

. . . . copies of patents may be obtained from the Commissioner of Patents, Washington 25, D. C., at 25 cents each . . . patents reviewed cover period January 5, 1954 through February 2, 1954 . . . .

DESULPHURIZATION OF IRON

▲ U.S. 2,665,982, issued January 12, 1954 to Francis T. Crego and Harold R. Fisher and assigned to Air Reduction Co., describes a method of desulphurizing and decarburization of molten iron in the open hearth process.

The inventors claim that the lime-to-silica ratio, during desulphurization, must be at least 2.5 to 1, and the slag must have a high fluidity which is obtained by adding fluorspar in sufficient quantity. Thus, from 500 to 600 lb of fluorspar must be added to the slag employed in a 70-ton basic open hearth steel furnace to effect the result. Oxidizing agents are eliminated during the desulphurization operation, since oxidation causes a reversal of the reaction between calcium and sulphur and the return of sulphur to the metal and retards the desulphurizing effect of the calcium present in the slag. Thus no iron ore or other oxidizing agent is employed during the desulphurization procedure.

To effect the necessary agitation during the desulphurization, an inert gas such as nitrogen is introduced through a pipe, as shown in Figure 1.

By operating in this way, the sulphur content of the metal may be reduced effectively in 10 to 20 minutes, as compared with an hour to three hours by conventional methods (for a 70-ton heat).

After the desulphurization has proceeded to the desired point, the slag is removed and a new slag is substituted. Decarburization may then be accomplished by the conventional method of adding iron ore or by the introduction of oxygen through a suitable pipe.

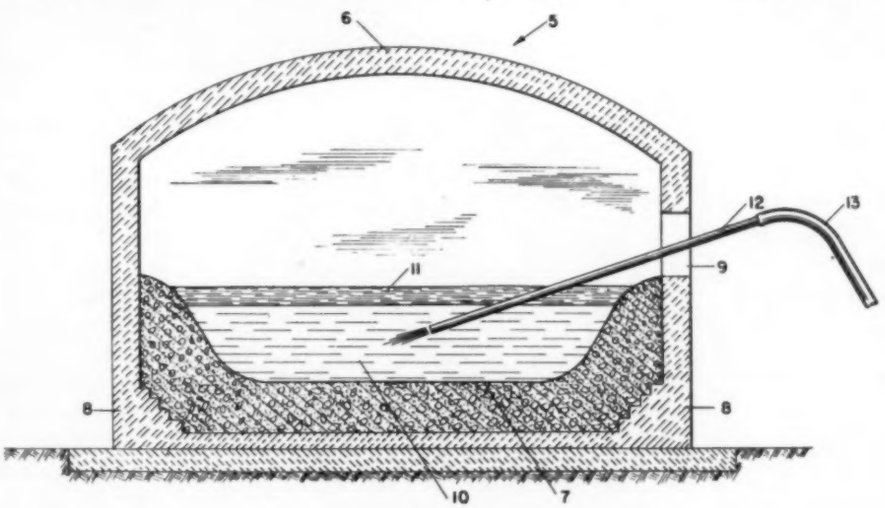


Figure 1

CONTINUOUS PICKLING AND REGENERATION OF PICKLE LIQUOR

In U.S. 2,668,130, issued February 2, 1954 to Edwin D. Martin and assigned to Koppers Co., Inc., an apparatus and method are described for continuous acid pickling of steel and continuous regeneration of the pickle liquor.

The present invention provides for a correlation between the acid content of the liquor and its temperature so as to obtain an optimum rate of pickling which is uniform for all portions of the strip. This is accomplished by maintaining an acid concentration of 16 to 20 per cent H_2SO_4 at a temperature between 200 and 210 F. A commercially valuable product, ferrous sulphate monohydrate, is recovered from the pickle liquor during the regeneration step. The temperature in the regeneration step is the same as in the pickling step. The presence of sulphate in the recycled pickle liquor does not slow down or otherwise affect the pickling operation, provided its concentration is kept below the saturation point. During the regeneration step, ferrous sulphate monohydrate is precipitated out by the addition of acid, which produces heat and reduces the solubility of the monohydrate. The monohydrate may be used as an ingredient

of fertilizer, in the manufacture of sulphuric acid, in making iron oxide pigments, etc. No waste whatsoever is produced.

The pickling apparatus is shown in Figure 2 and the regeneration process in Figure 3. In the pickling operation, four pickle tanks 50-53 are used. Regenerated pickle liquor at the proper concentration and temperature is introduced into the first tank 50 through a line 54 and the liquor flows successively through the four tanks in series. The spent pickle liquor is removed from the last tank 53 through a pipe 56. The strip metal is conducted through the four tanks concurrently with the flow of liquor.

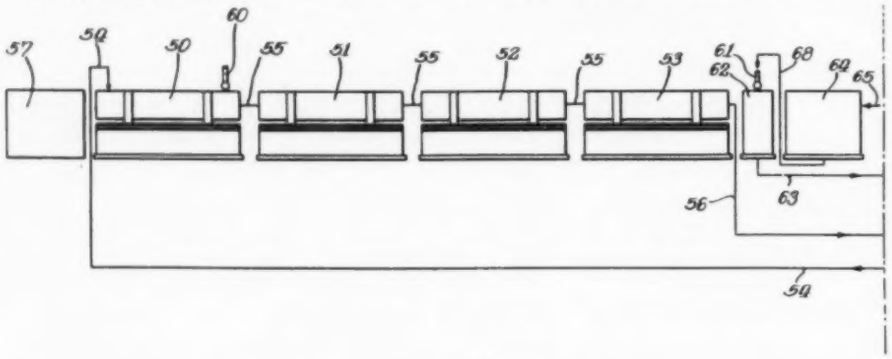


Figure 2

The metal is first heated by a heater 57 to a temperature higher than the pickling temperature, say 240–250 F. This provides additional heat for the process, and also facilitates the initial removal of scale when the temperature drops rapidly on immersion in the pickle liquor. The use of a mechanical scale breaker is thus dispensed with. A spray of warm water at point 60, between the first and second pickle tanks, is helpful in effecting the removal of the red oxide.

As the metal leaves the last pickle tank, it is washed with warm water, to remove pickle liquor. This water is later used in the regeneration step to dilute the regenerated liquor. This water washing is accomplished in two stages. The metal first passes under a spray 61, the water being collected in a tank 62 and being carried away by a pipe 63. The metal is then immersed in warm water in a tank 64 to complete the washing or rinsing. The spray and rinse water are maintained at about 200 F; thus the metal quickly dries in the air when it emerges from the rinse tank. The water in the rinse tank is constantly being replaced through inlet 65 and it then passes through the spray 61.

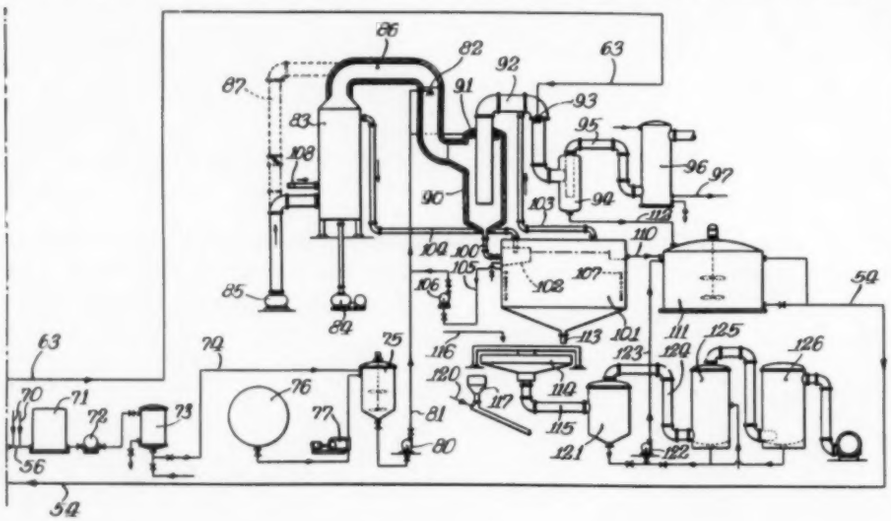


Figure 3

The spent pickle liquor from the last pickle tank 53 passes through pipe 56 to the regeneration apparatus shown in Figure 3, where it enters a surge tank 71. It is then withdrawn by pump 72 and passed to a filter 73, where solids such as scale are removed. The liquor then goes to a mixing tank 75 in which sulphuric acid is added, the acid being pumped from tank 76. The amount of acid added is equivalent to the ferrous sulphate produced in the process.

The fortified liquor is then pumped through a spray 82 located in a stream of hot gas, supplied from a gas-burning furnace 83 supplied with a gas booster pump 84 and an air blower 85. The flue gases are at about 2000 F. An air by-pass 87 regulates this temperature. From the spray, the liquor and gases are conducted to a centrifugal evaporator 90, in which additional liquor sprays 91 may be located. The gases pass to a point 93 where the rinse water is introduced as a spray to lower the temperature and condense most of the entrained moisture. The rinse water, condensate, and cooled gases then go to an entrainment separator 94, from which the gas goes to an electrical precipitator 96.

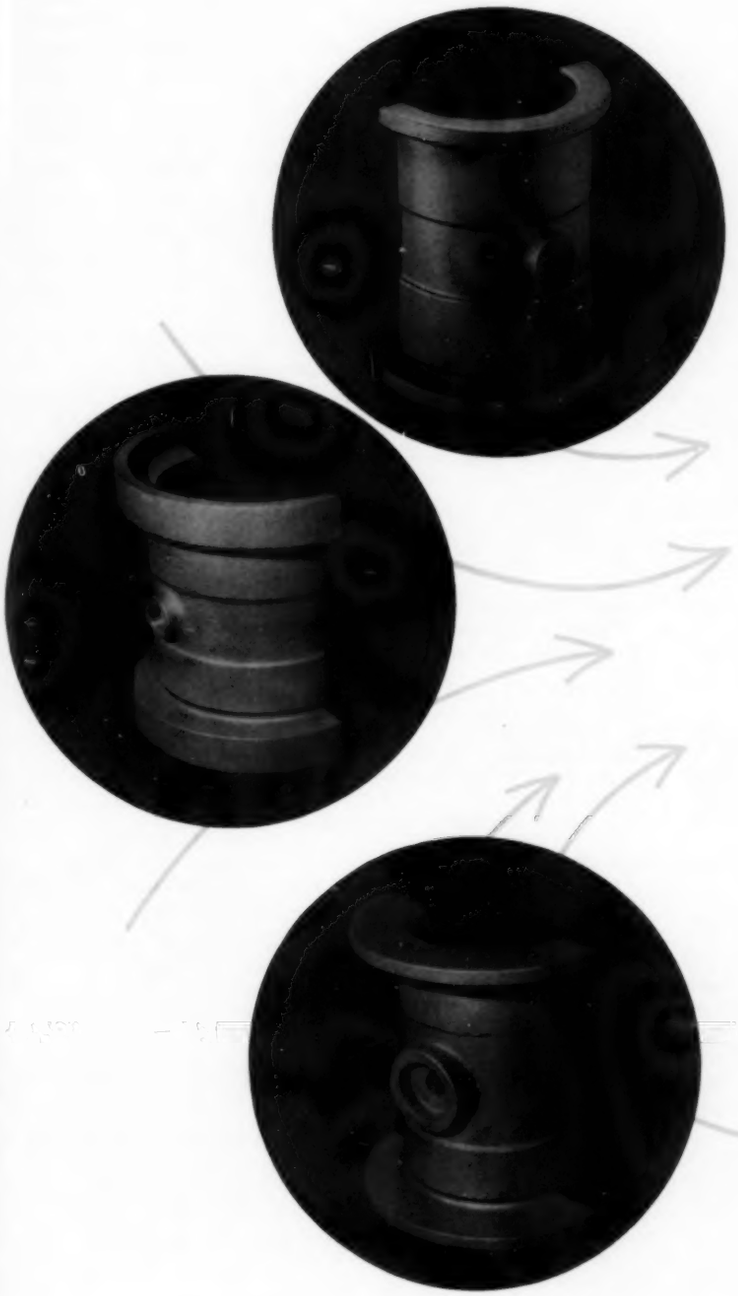
The concentrated liquor separated in the centrifugal evaporator 90 is drained into a settling tank 101 where the crystallized sulphate separates as a slurry from the supernatant liquor. Heat is supplied to the liquor in the settling tank, as required, by bubbling hot gases from furnace 83 through the liquor, or by means of steam coils 107. The supernatant liquor is withdrawn through a pipe 110, for dilution and reuse in the pickling tanks. It is diluted in tank 111 with water and condensate draining from the entrainment separator 94. The liquor is then pumped through line 54 back to the first pickle tank.

The sulphate monohydrate slurry is discharged to a filter 114 of the rotary disk type. The crystals are washed with cold water from pipe 116. The washed sulphate is discharged to a dryer 117, in which hot air is introduced at 120. The liquor and wash water discharge to a receiver 121, from which they may be pumped to the dilution tank 111. Vapors are carried to a condenser 125. Moisture-laden air from the condenser is carried to a vacuum type moisture trap 126.

SUSPENDED ROOFS FOR SOAKING PITS

Two recent patents describe suspended roof structures for soaking pits. The patents are U.S. 2,664,836, issued January 5, 1954 to John Rawlings, assignor of one-half to

WHY SHELL-MOLDED BRONZE BEARINGS COST LESS AND WEAR LONGER



National Bearing's carefully controlled *shell molding* practice makes extremely close-tolerance casting possible. This eliminates the need for costly machining and metal waste. It permits retention of a greater portion of the tough outer cast shell . . . *a guarantee of greater service life.*

Add to this the fact that if oil grooves are required, they can be cast in; if drilling is specified, castings are drilled prior to shipment so that they are ready for installation when received by you . . . and you have the answer to why *shell-molded* bearings cost less and wear longer.

And remember, six modern National Bearing plants insure quality workmanship and prompt delivery. They, in turn, are backed by extensive engineering and research facilities of the entire American Brake Shoe Company.

So investigate National SM castings for use as line shaft, crane, run-out table, and other similar replacement parts.

OTHER NBD PRODUCTS FOR THE STEEL INDUSTRY

Bosh Plates	Stack Plates
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AMERICAN Brake Shoe COMPANY

NATIONAL BEARING DIVISION

4930 Manchester Avenue, St. Louis 10, Mo.

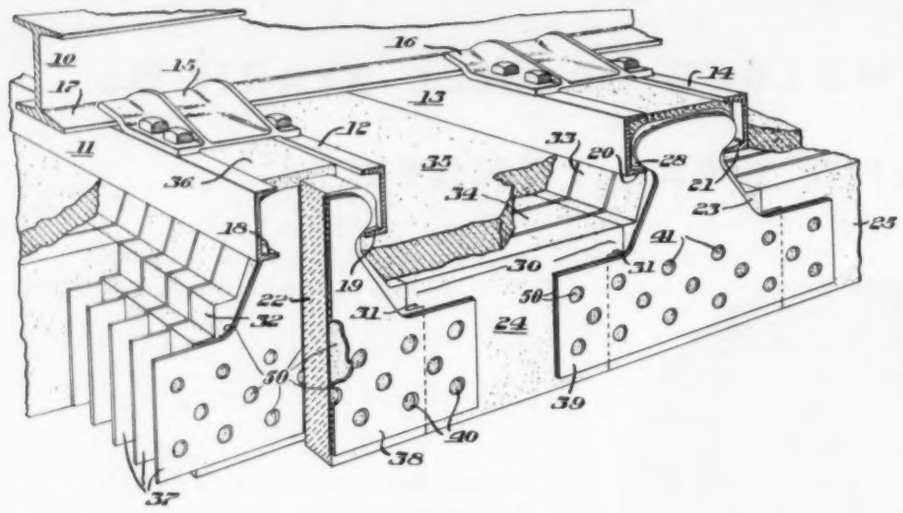


Figure 4

Ralph T. Hadley, and U.S. 2,664,837, issued the same day to Robert A. Banck and assigned to Bigelow-Liptak Corp.

In conventional suspended arch construction for a soaking pit, all of the refractory blocks are arranged in a single layer with their lower surfaces in a common horizontal plane, and their weight is supported by overhead stringers. The suspended blocks must be strong to be self-supporting and are made of the highest quality of fire-clay. Such high quality blocks have relatively high strength, but are

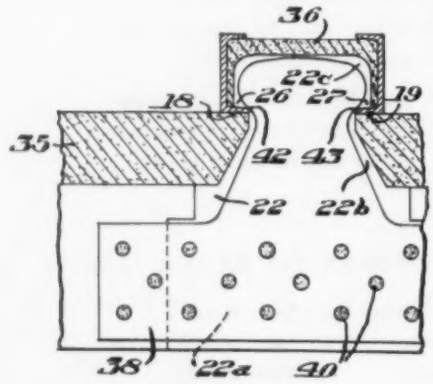


Figure 5

expensive, and also are brittle and easily cracked, especially when ingots suspended by a crane are brushed against the cover or when the cover is being moved about by a crane. The integral hanger of each suspended block has a relatively small neck and relatively small projections engaging the supporting stringers, and the neck and projections are particularly likely to crack and destroy the supporting connection between the body of the suspended block and the stringers overhead. The blocks in the cover are also subject to injury through spalling of their lower surfaces. This is caused by rough handling and by uneven expansion or contraction of the blocks when a cool cover is placed over a hot furnace, and when a hot cover on a furnace is removed into a region of comparatively cool air. Repairing and rebuilding the refractory structure of the cover is an expensive operation and may cause even more expensive production delays.

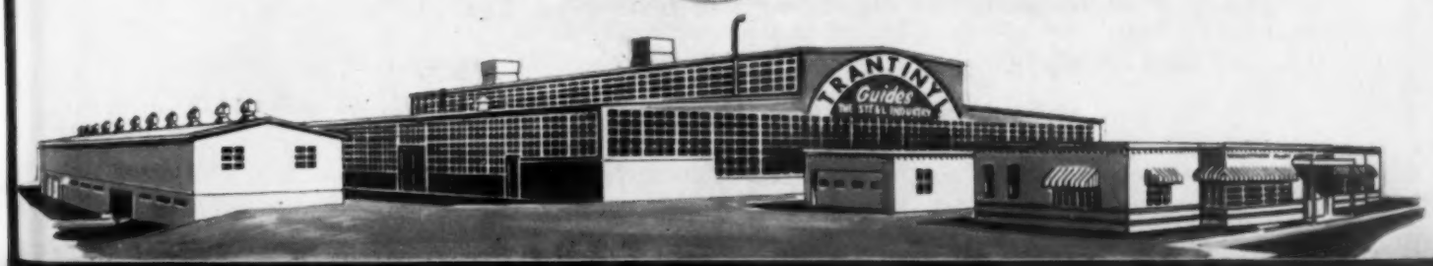
In U.S. 2,664,836, as shown in Figures 4 and 5, flanges 18-21 on the stringers 11-14 support refractory blocks 22 and 23, which in turn support refractory block 24. As shown, the suspended blocks have a "hanger portion" at the top, to permit them to be suspended from the flanges 18-21. Layers of insulating material 35 are spread over the successive courses of blocks between the necks of the suspended blocks and similar insulating material 36 is spread between each pair of stringers over the enlarged portions of the suspended blocks carried by the stringers. This construction is conventional in soaking pit covers. The novel feature is

OTHER PATENTS OF INTEREST TO THE IRON AND STEEL ENGINEER

Patent No.	Date	Subject	Inventor or Assignee
2,664,838	1/ 5/54	Hinged bulkhead for closing slag pockets of open hearth furnaces	M. H. Detrick Co.
2,664,901	1/ 5/54	Apparatus for quenching small steel parts	General Electric Co.
2,665,191	1/ 5/54	Preparation of ferrous chloride from iron oxide containing material	Republic Steel Corp.
2,665,205	1/ 5/54	Hot work steel alloy	Allegheny Ludlum Steel Corp
2,665,242	1/ 5/54	Coke oven heating walls	Carl Otto
2,665,318	1/ 5/54	Arc melting of titanium to form ingots	Allegheny Ludlum Steel Corp.
2,665,362	1/ 5/54	Manufacture of pipe	Republic Steel Corp.
2,665,895	1/12/54	Soaking pit curb wall with fixed elevation	Amsler Morton Corp.
2,665,899	1/12/54	Apparatus for the roasting of ores	Compagnie des Metaux d'Overpelt-Lommel et de Corphalie S.A.
2,666,003	1/12/54	Continuous heat treating of cold rolled steel strip	Bethlehem Steel Co.
2,666,220	1/19/54	Drying refractory linings of furnaces	Paul Blanchard
2,666,534	1/19/54	Automatic air operated bar turner	Inland Steel Co.
2,666,590	1/19/54	Drop hammer	Taylor-Wharton Iron and Steel Co.
2,666,697	1/19/54	Ferrous alloy for high temperature abrasion resistance	Mathias L. Eder and Louise J. Eder
2,666,724	1/19/54	Preparation of iron powder of improved electromagnetic properties	General Analine & Film Corp.
2,667,065-6	1/26/54	Hardness tester	Alfredo Ernst
2,667,067	1/26/54	Hardness tester	Cabul Tool Co., Ltd.
2,667,276	1/26/54	Device for transferring ingot molds	United States Steel Corp.
2,667,343	1/26/54	Heat transfer checker work	The Carborundum Co.
2,667,433	1/26/54	Tin coating iron articles by diffusion	Meinecke Metallurgie G.m.b.H.
2,667,455	1/26/54	Electrolytic production of iron from iron sulphate solutions	Pyror, Ltd.
2,667,524	1/26/54	Induction heating furnace for heating metallic articles	Allmanna Svenska Elektriska A.G.
2,668,040	2/ 2/54	Furnace for heating billets	Selas Corp. of America
2,668,048	2/ 2/54	Foundry cupola	Robert A.M. Ronceray
2,668,054	2/ 2/54	Apparatus for positioning strip	United States Steel Corp.
2,668,075	2/ 2/54	Coke oven door	Koppers Co., Inc.
2,668,105	2/ 2/54	Production of sponge iron	Fredrik W. de Jahn and Alan N. Mann
2,668,106	2/ 2/54	Method of making charging ore for open hearth furnaces	Illinois Clay Products Co.
2,668,183	2/ 2/54	Electrode suspension mechanism	Elektrokemisk A/S

TRANTINYL

guides the steel industry



YOUNGSTOWN ALLOY CASTING CORP., • YOUNGSTOWN, O.

ROLLING MILLS: bar, hoop, strip, shape mill guides, and rollers. SEAMLESS TUBE MILLS: guide shoes, rolling mill plugs and rolls, piercer points, etc.
ELECTRIC WELD TUBE MILL: forming rolls, planishing rolls, tool holders, etc. • STRAIGHTENING MACHINE GUIDES • HEAT RESISTING CASTINGS

the use of reinforcing steel sheets 37 between adjacent courses of the refractory blocks with an edge of each sheet engaging a supporting stringer. Steel sheets of 20-22 gage are preferred because they are thin enough to minimize heat losses caused by conduction of heat through the sheets, and yet are strong enough to reinforce the courses of the refractory blocks effectively. Adjacent sheets are spaced to allow for thermal expansion. Each sheet is perforated as shown at 40 in the sheet 38 so that the sheets may be securely mortared between the adjacent suspended and intermediate blocks. The mortar 50 flows through the perforations and after the mortar hardens it opposes any movement of the sheets between the adjacent blocks. Thus, failure of the hanger portions of either of the adjacent suspended blocks will not cause the block having the cracked hanger to fall down into the furnace, or to add its weight to the load which must be supported by the hangers of adjacent suspended blocks. Furthermore, the sheets extend alongside the lower edges of the suspended and intermediate blocks and hold up pieces of the adjacent blocks which might otherwise break away as a result of spalling action. The fact that the sheets conduct some heat is not a disadvantage, because it tends to equalize the temperatures at the upper and lower portions of the blocks and thereby reduces spalling as a result of uneven thermal contraction and expansion.

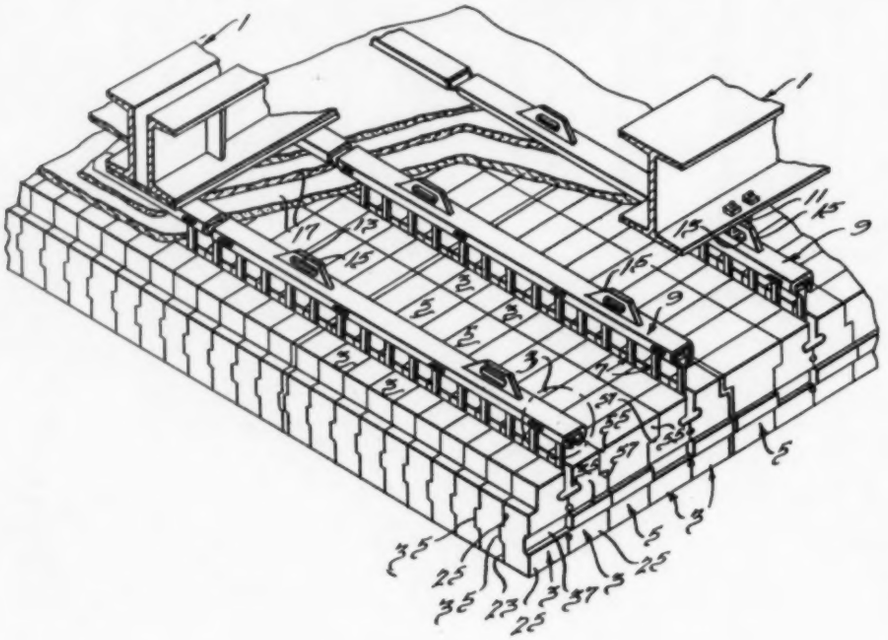


Figure 6

U.S. 2,664,837 describes a novel type of hanger bar which makes it possible for one hanger at a time to be removed without disturbing adjacent hangers. The features of this invention are shown in Figures 6, 7, and 8. Removal of one of the hangers 7 is accomplished by rotating it through 90 degrees, in which case its shoulder 45 will slide through the opening 49 at the bottom of the hanger bar 9. As shown in the drawings, each hanger supports two blocks 3 and one block 5.

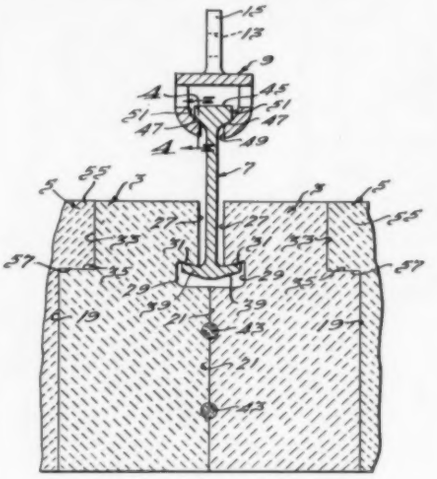


Figure 7

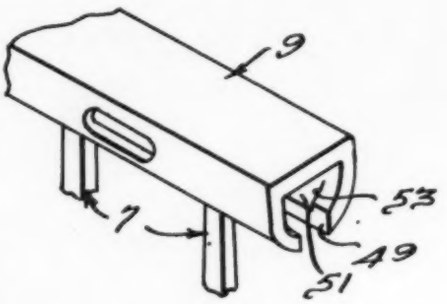


Figure 8

There is a demand for copies of the following Yearly Proceedings:

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1941 **1942** **1943**
1947

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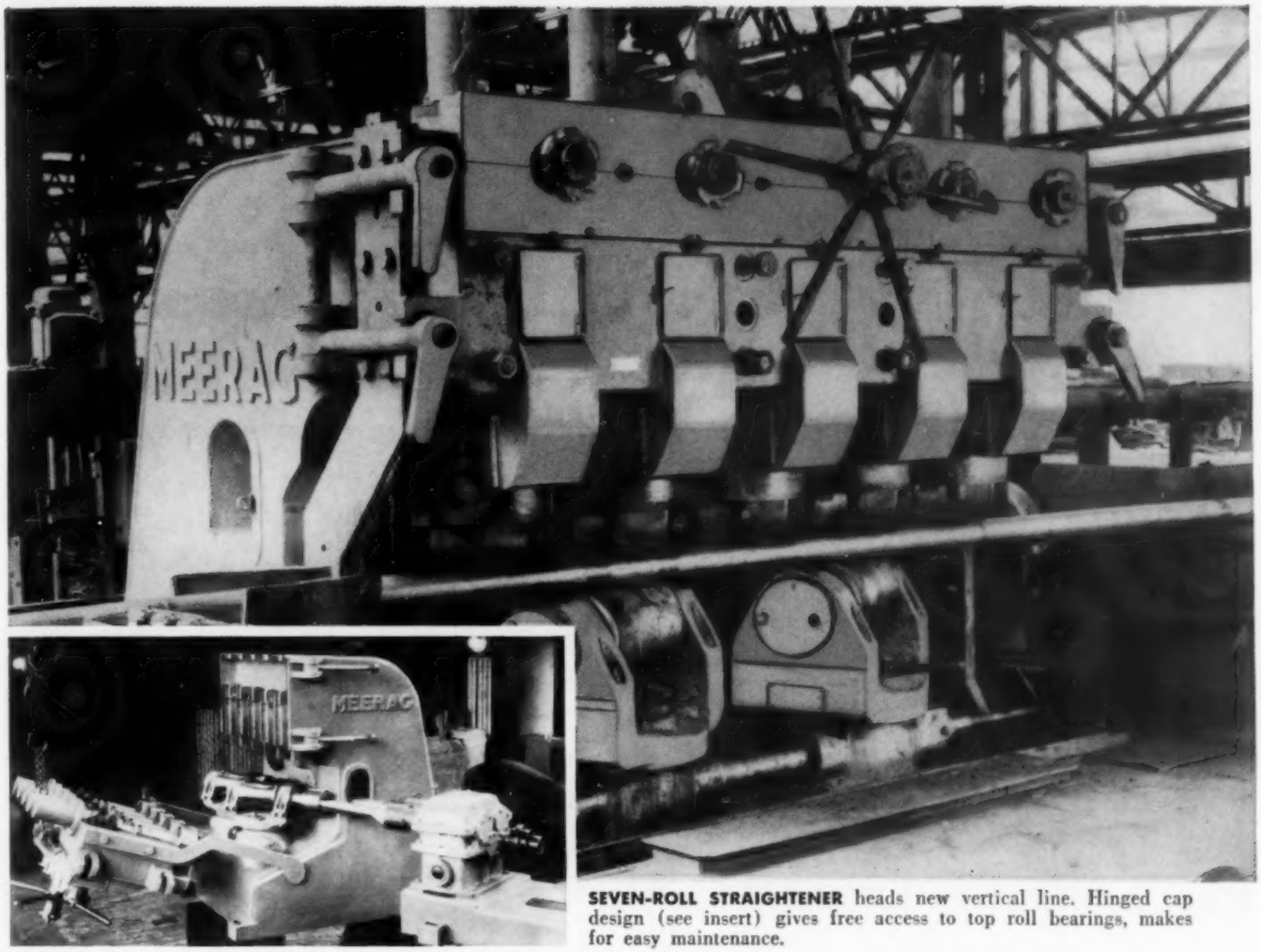

SEVEN-ROLL STRAIGHTENER heads new vertical line. Hinged cap design (see insert) gives free access to top roll bearings, makes for easy maintenance.

New straightener line speeds mill production

• Straighten tubes and bars at high speed in a single pass without yield marks? Handle a wide range of stock sizes with each set of rolls? You can do both with one of the new Mannesmann-Meer vertical skewed roll straightening machines.

The large number of these Meer rolls and their special hyperbolic shape improve the surface quality of the work piece, and prevent yield marks which ordinarily result when stressing material through the elastic limit. Vertical arrangement of the rolls helps speed production by keeping bottom level of the straightened material constant for easier access to inlet and outlet tables. All rolls and shafts are supported in anti-friction bearings, and perfect synchronization is insured by a special Mannesmann-Meer drive.

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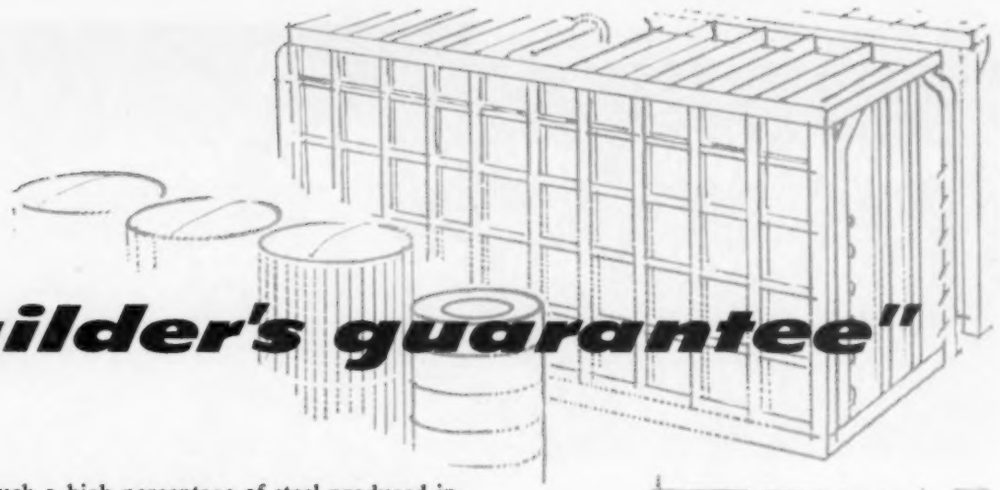


the builder's guarantee"

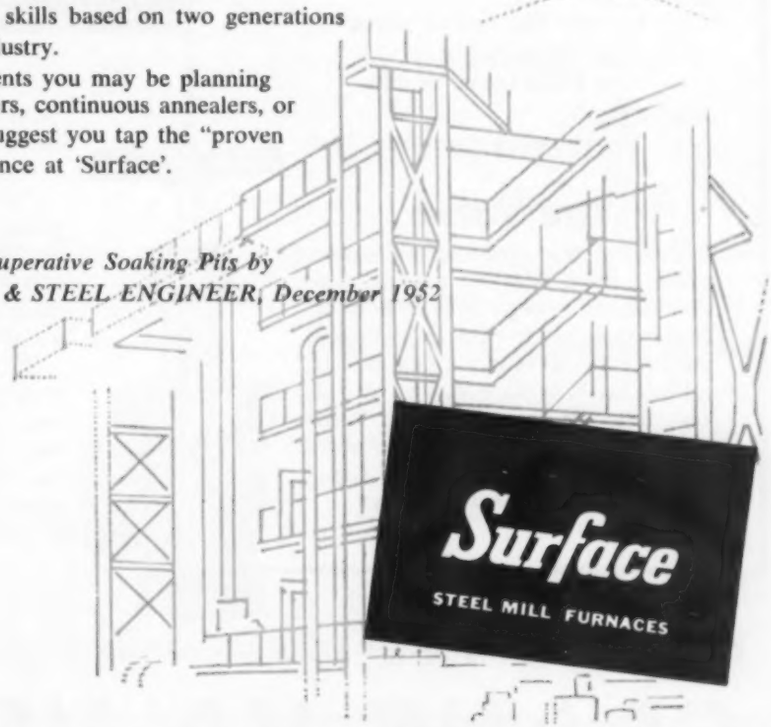
Why is it that such a high percentage of steel produced in this country passes through Surface Combustion equipment in one or more stages of its processing? Part of the answer might be furnished by a list of steel making advances in which our engineers have participated. The one-way fired soaking pit . . . the remotely located single recuperator serving a number of holes . . . the research which led to substantial increase in pit sizes without sacrificing the simplicity of the one-way firing principle . . . the jet pump which facilitates handling heated air in high volumes with low equipment maintenance . . . these you may recall as developments to which 'Surface' engineers contributed.

There's a more basic answer however: typically expressed in a customer's published report of comparatively recent 'Surface' soaking pit installation: "tons per hour . . . and fuel savings as shown by Btu/ton figures . . . has *surpassed the builder's guarantee.*"

This business of making one's word good is by no means unique at 'Surface'. We like to believe however that we combine this old-fashioned way of doing business with an exceptionally effective combination of metallurgical and construction skills based on two generations of experience and growth with the steel industry.

Whatever long-range capital investments you may be planning in soaking pits, slab heaters, annealing covers, continuous annealers, or any equipment involving combustion, we suggest you tap the "proven resources" of cost-saving skills and experience at 'Surface'.

"Operative Results of One-Way Fired Recuperative Soaking Pits by E. H. Cauger and J. C. Stamm, Jr., IRON & STEEL ENGINEER, December 1952

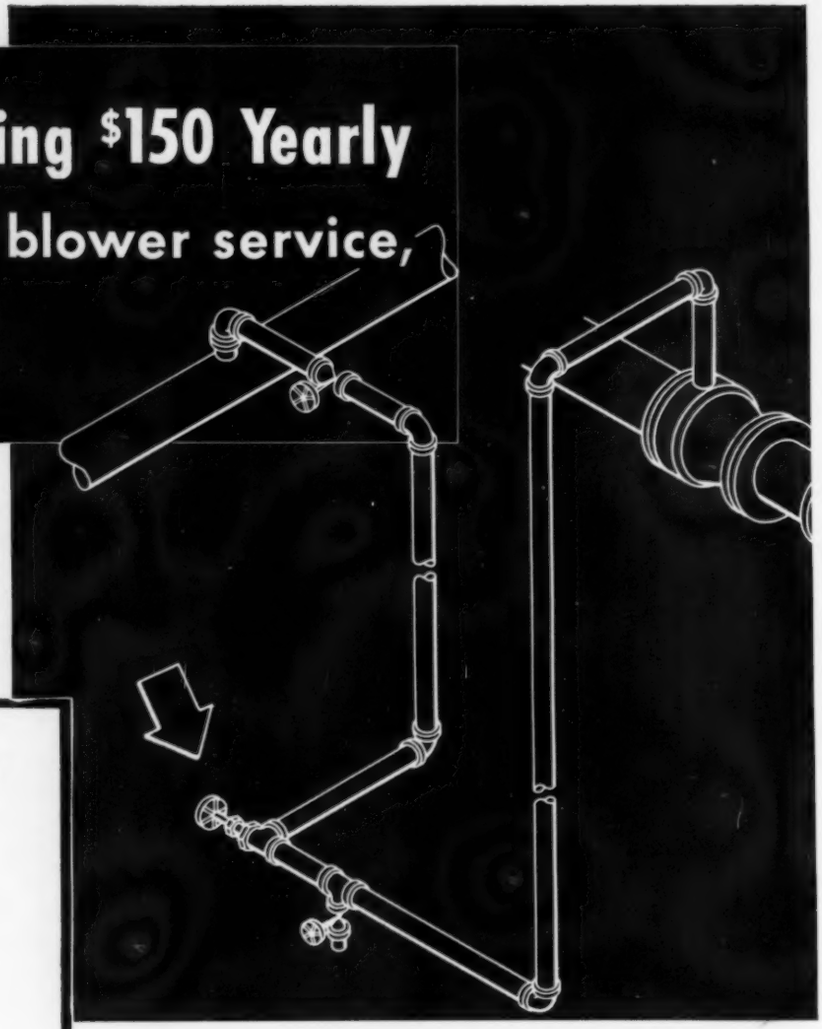


SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

One-way fired soaking pits • Billet reheating furnaces • Slab heating furnaces • Continuous type, controlled atmosphere strip annealing and normalizing furnaces • Controlled atmosphere annealing covers for wire and rod • Controlled atmosphere annealing covers for coil and sheets • Continuous furnaces for heat treatment of steel plate • Controlled atmosphere furnaces for carbon correction in high alloy rod and bar stock • Continuous type bright annealing and normalizing furnaces • Prepared gas atmosphere generating equipment • Pit type convection furnaces for rod annealing • Stress relief furnaces • Wire patenting furnaces

Single Valve Saving $150 Yearly

. . . on severe ash blower service, for example . . .



The Installation

At City Light & Power Company, Washington, Indiana—with Crane bronze angle valve in 2-inch steam line to boiler ash blower manifold. Working pressure: 300 psi, 525 degrees F.

Valve Service Ratings

SUITABILITY:
Perfect match for needs

FEATURES:
Crane Plug Type Disc

MAINTENANCE COST:
One stem replaced in 3 years

SERVICE LIFE:
Already 12x former valves

OPERATING RESULTS:
Over $400 saved to date

AVAILABILITY:
Crane catalog item—No. 384P

The Valve

Crane plug-type disc and seat design make a most effective seating combination for tough steam service. Highly resistant to damage by foreign matter, wire-drawing, erosion, cutting, galling, etc. The wide tapered disc allows fine, accurate throttling. These rugged bronze valves come in globe and angle patterns; see your Crane Catalog or Crane Representative.

The Case History

Valves formerly had to be replaced every 8 to 12 weeks, their cost alone exceeding $150 yearly. It's a tough spot even for a good valve.

The valve's location in the steam line is below the boiler water level. Each operating cycle exposes it to a long leg of condensate, with an abrupt change to hot steam direct from the boiler header. On closure, the valve is again subject to cooling, and that's the cycle about 8 times daily.

Under those conditions, this Crane No. 384P Bronze Plug Type Disc Angle Valve put a stop to former replacement cost, saving more than $400 in 3 years since installed. Still the valve remains tight, dependable, and fully fit for service. That's the result of choosing the right valve—the choice assured by Crane quality and the completeness of the Crane line.

THE BETTER QUALITY...BIGGER VALUE LINE...IN BRASS, STEEL, IRON

CRANE VALVES

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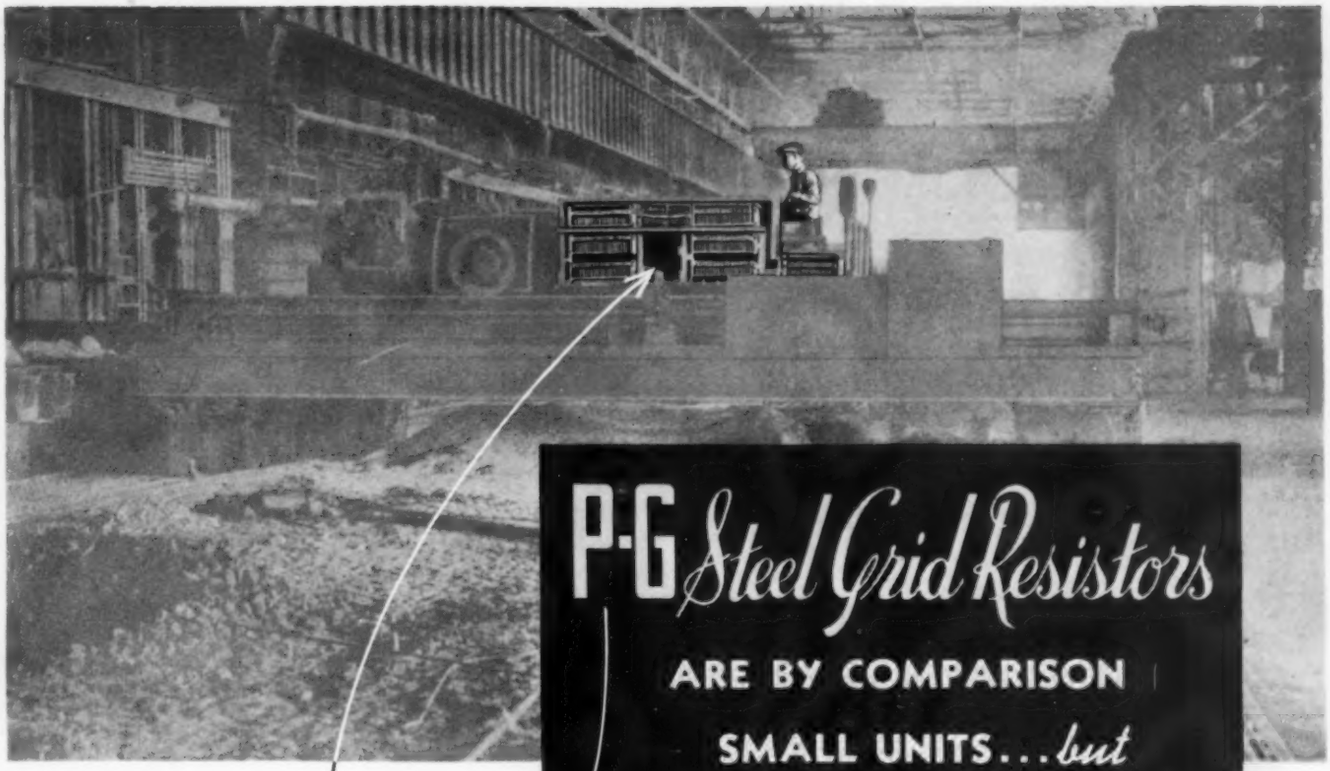
VALVES • FITTINGS • PIPE • PLUMBING • HEATING



P-G *Steel Grid Resistors*

ARE BY COMPARISON SMALL UNITS... *but so important to production*

- Steel Construction
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- Corrosion Resistant
- Vibration Proof
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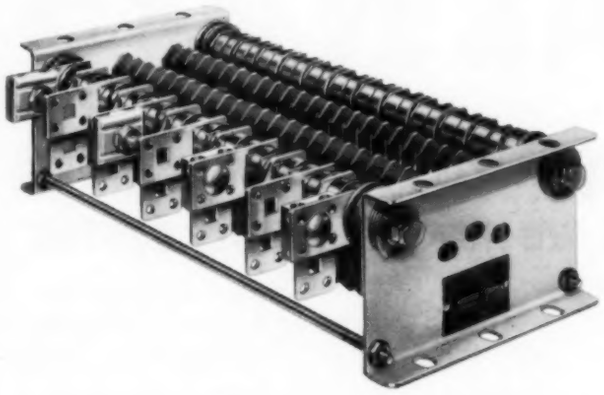
- Provision for Expansion
- Adequate Ventilation
- Rugged Terminals



Resistors represent only a small part of a charging machine, but the duties they perform are of the utmost importance to its operation. In this stage of steel making, a charging machine must be able to start, stop, reverse and change speed regularly and continuously during its operating cycle. P-G Steel Grid Resistors have been handling their part of this job with a remarkable service record in many plants. For continuous "Trouble-Free Service" on this and all other steel mill applications, specify P-G.

Write for Bulletin No. 500

P-G

The Nonbreakable Steel Grid Resistor

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

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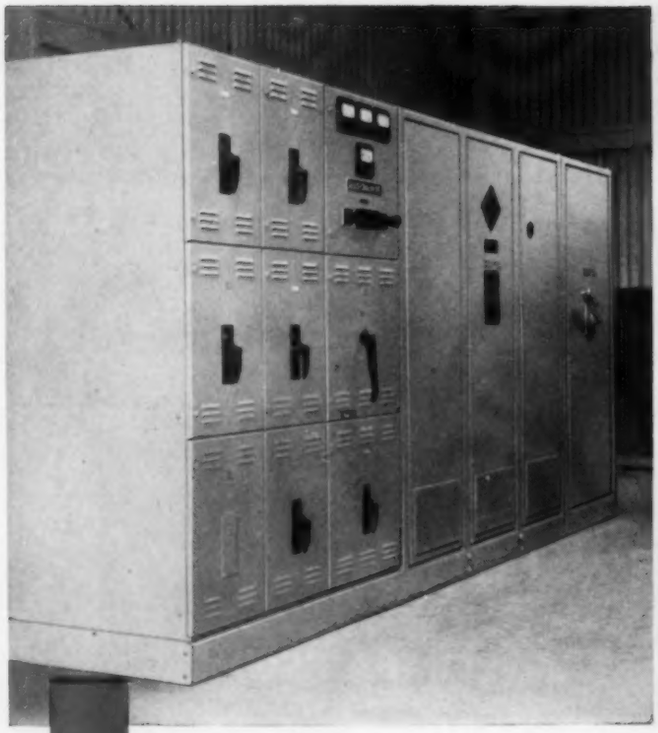
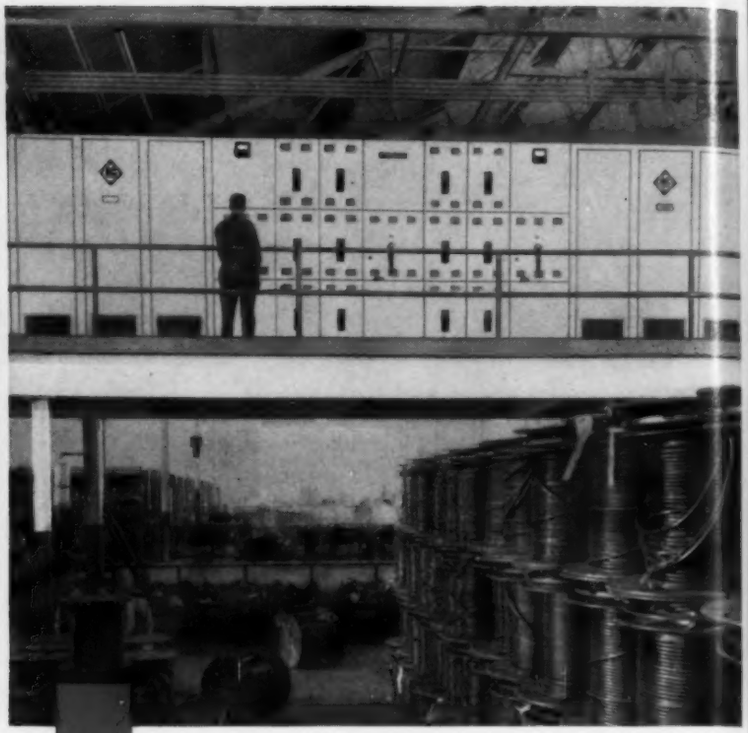


ON ROOF

Here's a spot out of the way of production flow — ideal for a unit substation. Lines to machines are short and direct. Either outdoor units or indoor units inside an enclosure can be used.



ON BALCONY

Here's another way to conserve valuable floor area! Substation is out of the way — yet right where it does the most good. While construction of balcony must be sturdy, it need not be expensive.

THERE'S ALWAYS

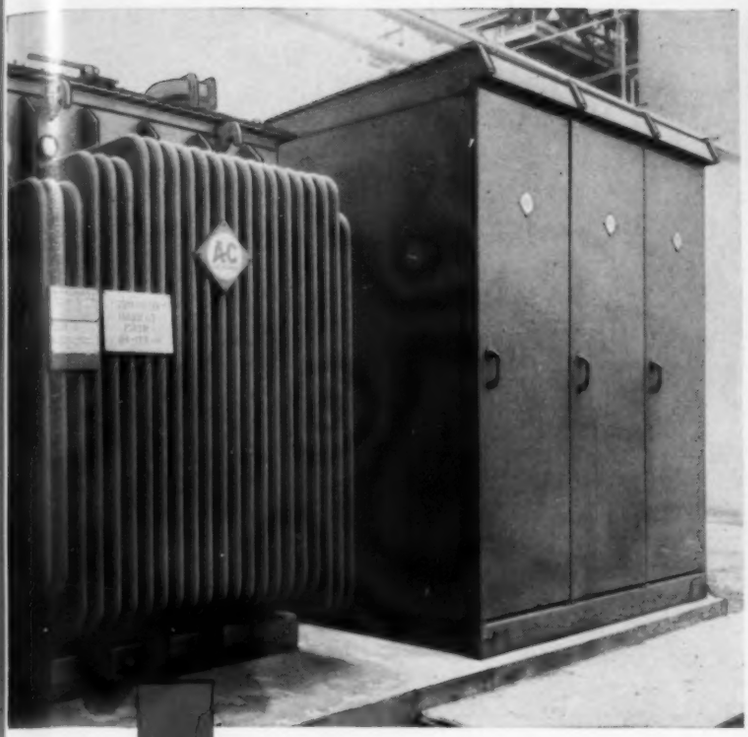
Modernize electrically with Allis-Chalmers switchgear placed in nonproductive space

• Bringing high voltage lines close to load centers is no problem with compact Allis-Chalmers unit substations. They fit anywhere . . . on the roof . . . on a balcony . . . in the basement . . . or outside near the building.

• Allis-Chalmers unit substations simplify the problem of keeping electrical distribution in step with increased power usage; help you get full production out of tools and equipment; and help you improve operating costs.

A-C ALLIS-CHALMERS

ALLIS-



NEAR BUILDING

If indoor atmosphere is hazardous or floor space and overhead space are at a premium, outdoor weatherproof unit substations can be placed near building.

IN BASEMENT

Where basement-located pumps or compressors are the main load or where machinery is light in weight, substations are often placed under the main floor.

ROOM

GET COMPLETE INFORMATION

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AVOID THESE LOSSES BY USING UNIT SUBSTATIONS

Reduced Motor Torque — Torque and horsepower drop when voltage drops. Unit subs improve voltage by shortening low voltage cable runs.

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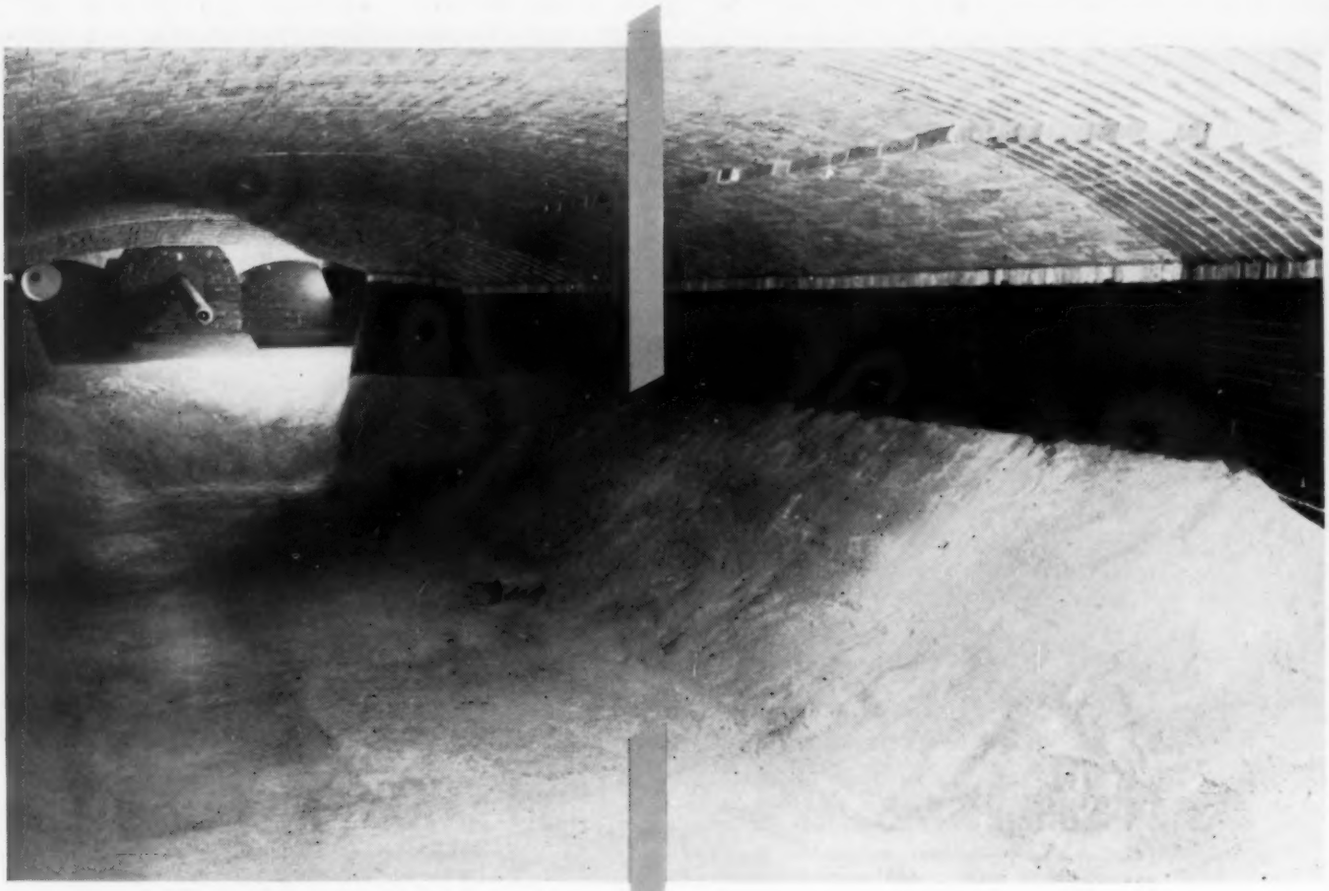
Lost Dryer Output—10% undervoltage cuts output of infrared oven 15%.

Lost Overload Capacity — Overload capacity drops about 10% for every 5% below rated voltage.

High Cable Costs — Savings in cable alone can go a long way toward modernizing a distribution system.

A-4246

CHALMERS



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A NEW 92% Magnesia Ramming Mixture for open hearth furnace bottoms

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  Over 4000 psi crushing strength after heating to 2910°F.
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  172 lb. per cu. ft. (rammed)
- **LOW SHRINKAGE**
  Less than 1% when reheated to 2910°F. (ASTM C 113-46)
- **MADE FROM HIGH-PURITY SEAWATER MAGNESITE**

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World's Largest Producer of Refractories
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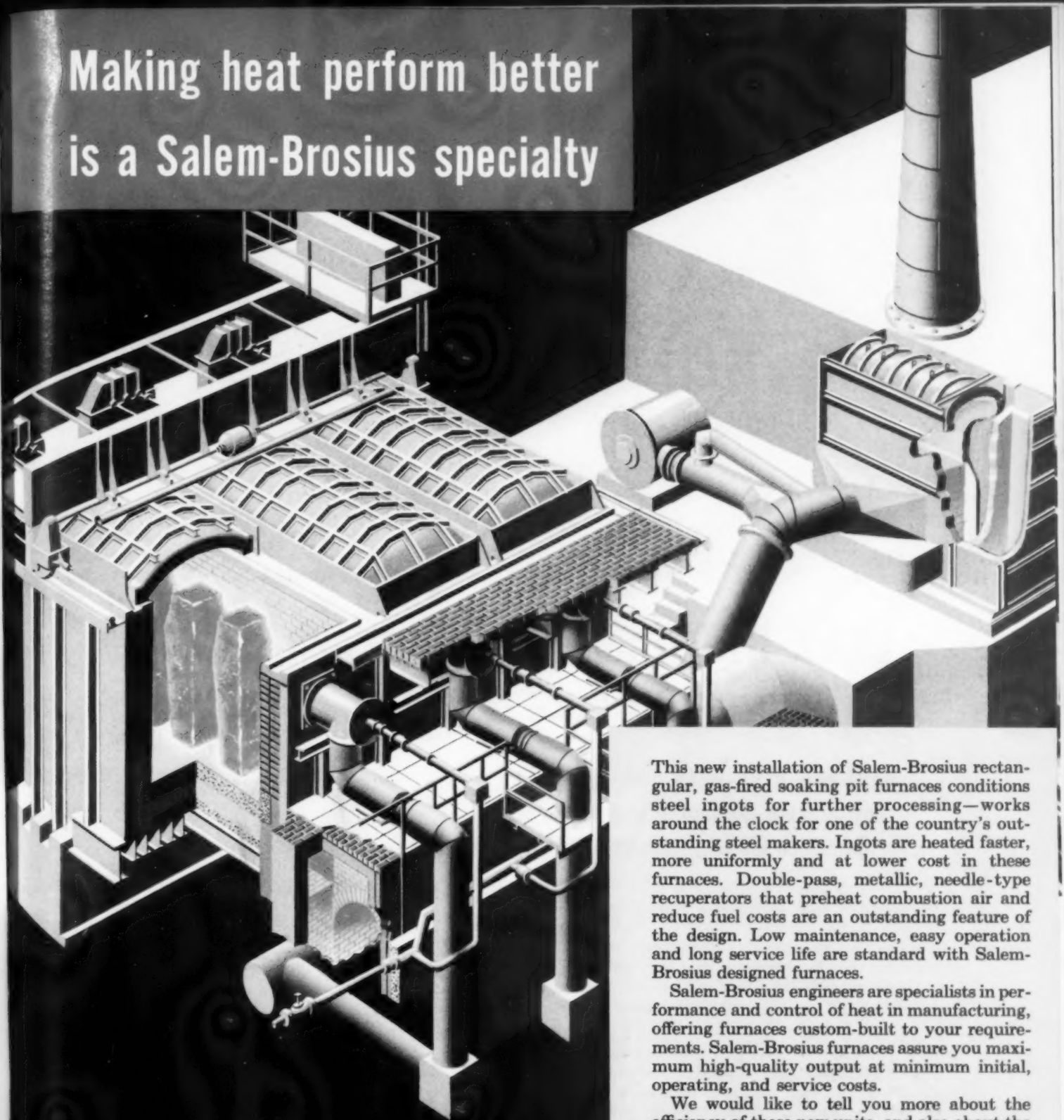
Making heat perform better is a Salem-Brosius specialty



This new installation of Salem-Brosius rectangular, gas-fired soaking pit furnaces conditions steel ingots for further processing—works around the clock for one of the country's outstanding steel makers. Ingots are heated faster, more uniformly and at lower cost in these furnaces. Double-pass, metallic, needle-type recuperators that preheat combustion air and reduce fuel costs are an outstanding feature of the design. Low maintenance, easy operation and long service life are standard with Salem-Brosius designed furnaces.

Salem-Brosius engineers are specialists in performance and control of heat in manufacturing, offering furnaces custom-built to your requirements. Salem-Brosius furnaces assure you maximum high-quality output at minimum initial, operating, and service costs.

We would like to tell you more about the efficiency of these new units, and also about the well-known Salem-Brosius circular soaking pits.

If your modernization or expansion plans call for heating or heat treating furnaces of any kind, furnace charging or forging manipulation equipment, valves, or hot materials handling machinery; write, wire, or phone Salem-Brosius!

Salem-Brosius, Inc.

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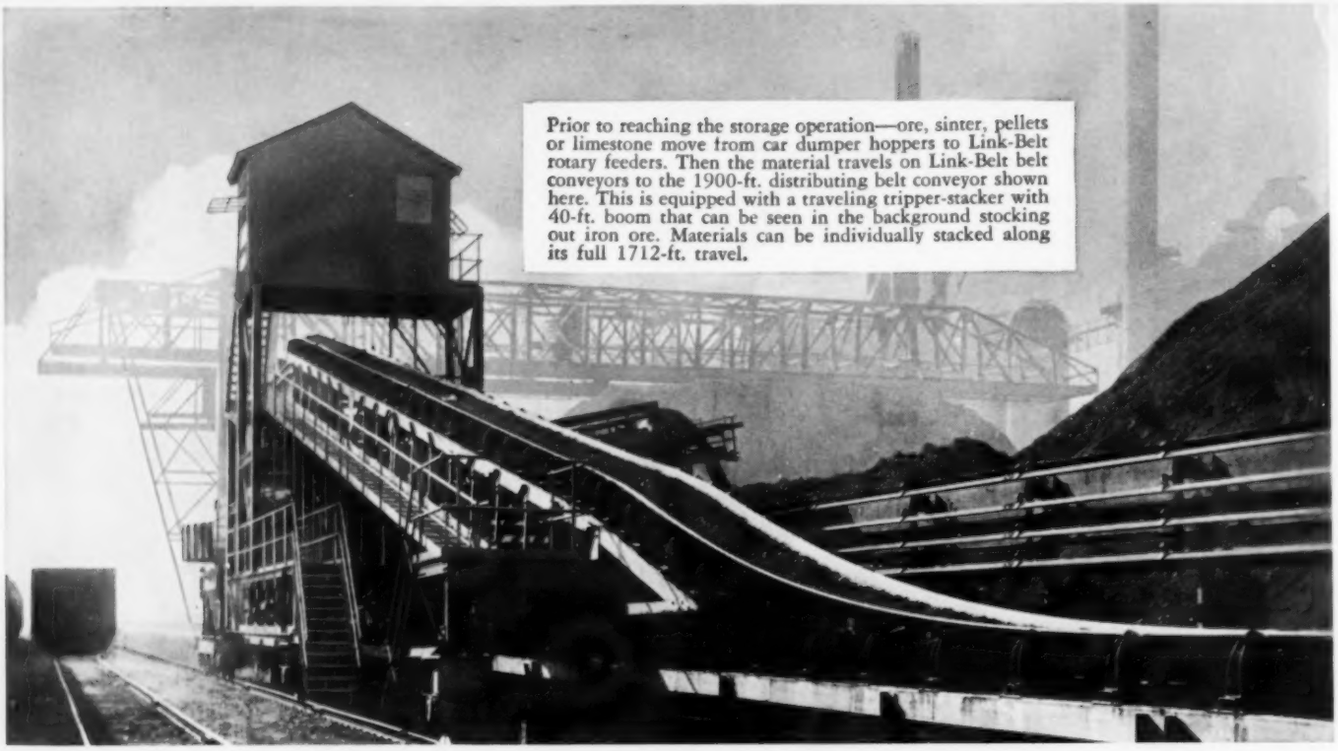


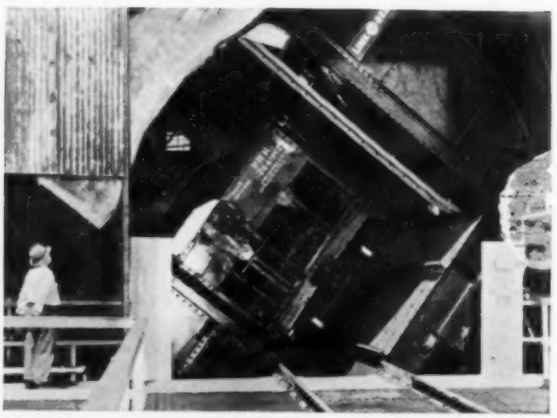
Prior to reaching the storage operation—ore, sinter, pellets or limestone move from car dumper hoppers to Link-Belt rotary feeders. Then the material travels on Link-Belt belt conveyors to the 1900-ft. distributing belt conveyor shown here. This is equipped with a traveling tripper-stacker with 40-ft. boom that can be seen in the background stocking out iron ore. Materials can be individually stacked along its full 1712-ft. travel.

LINK-BELT accepts full responsibility for successful bulk handling operation

Read how LINK-BELT designed, built and erected unloading and storage facilities for large eastern mill

So satisfactory was the seven-year record of the Link-Belt coal handling system at this large steel mill, they again called on Link-Belt to modernize their other bulk handling. Now, from railroad car unloading to storage, Link-Belt has mechanized the movement of iron ore, sinter, pellets and limestone.

Link-Belt designed, built and erected the complete raw materials handling system for this mill—including such details as enclosures and electrical wiring. When you rely on Link-Belt as a single source, Link-Belt accepts full responsibility for placing your system in successful operation. Our engineers will also work with your own engineers, consultants and builders of mill and process equipment—help you get the best in modern handling of steel and raw materials in every form. For complete information, call the Link-Belt sales office near you.



Completely automatic Link-Belt rotary dumper easily unloads up to 30 hopper-bottom and gondola cars per hour.

Dual motor drive to head of 1900-ft. long conveyor employs Link-Belt 200-hp and 150-hp parallel shaft gear drives.

LINK-BELT

MATERIALS HANDLING, PROCESSING AND POWER TRANSMISSION MACHINERY

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13.534

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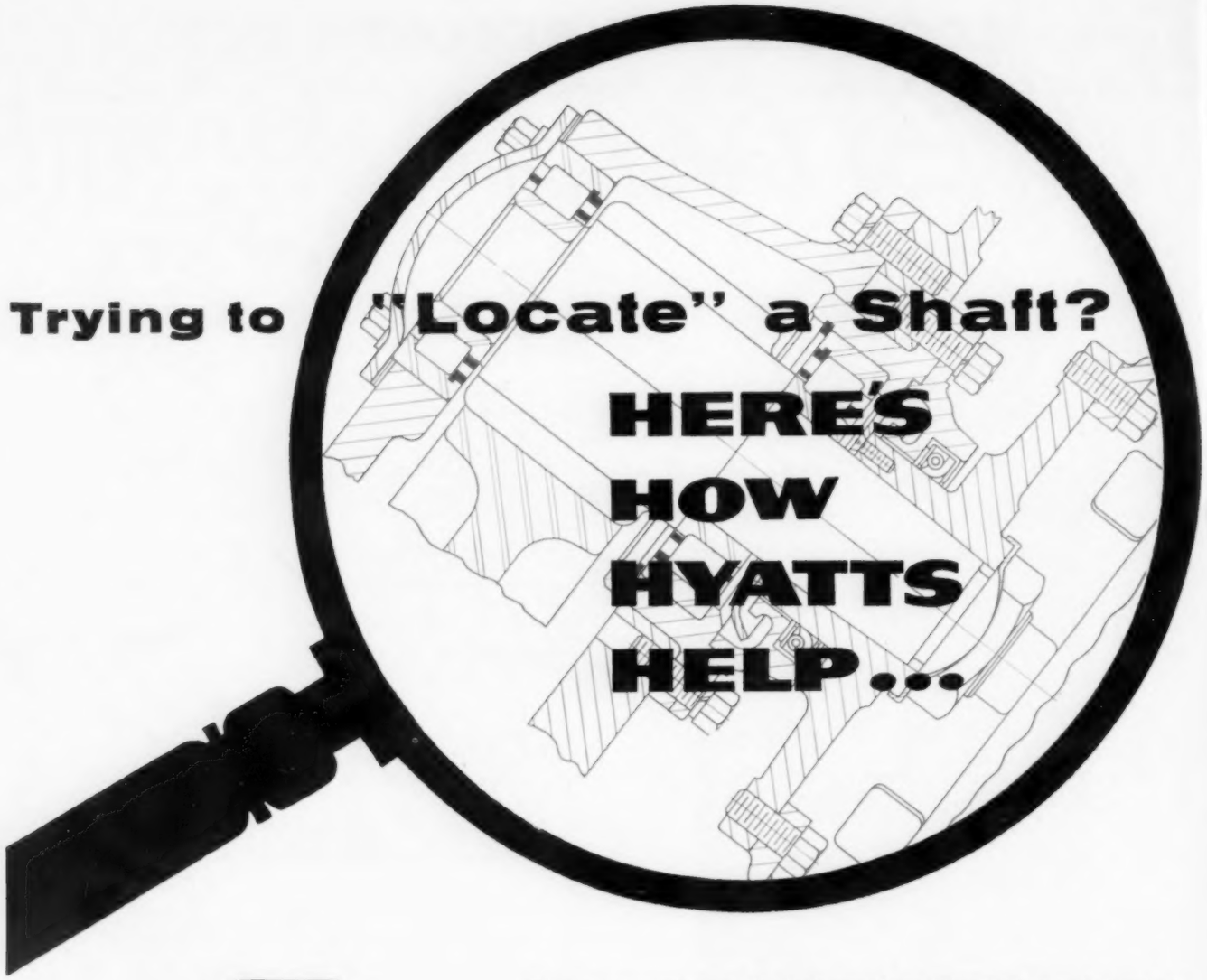
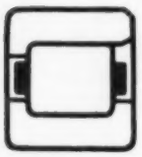
BETTER— PRODUCT—PACKAGE—PRICE— FASTER

Trying to "Locate" a Shaft?

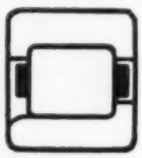


HERE'S HOW HYATTS HELP...

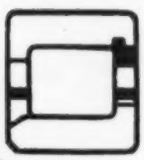
3 TYPES



BU-L
separable outer race series



R-WB
separable inner race series



R-YS
separable inner race series

Shown in section at the left are three Hyatt Hy-Load Bearing types that are used for axial shaft location. Flanges on inner or outer races limit axial shaft movement and permit the bearing to take light, intermittent thrust loads.

Since Hyatt inner races are assembled on shafts, with relatively heavy press fits, no accessory parts are necessary to hold them in place.

Hyatt Hy-Load Bearings are available with a variety of combinations of race flanges, snap rings, cages or separators, so that just the right combination can be selected for each set of operating conditions.

Hy-Loads are available in three diameter series, two widths and a complete range of sizes. For complete information write for Catalog 150—Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey.

HYATT ROLLER BEARINGS

STRAIGHT BARREL TAPER

ENGINEERING REPORTS:

G.E. powers world's fastest rod mill

Co-ordinated General Electric drive system helps Jones and Laughlin produce rod at record-breaking 5000 fpm

The fastest Rod Mill in the world—Jones and Laughlin's Aliquippa, Pa. mill—produces high-quality steel rod at the record-breaking speed of 5000 fpm. Powered by a co-ordinated General Electric drive system, the new three-strand mill, placed in full operation last year, produces 26,000 tons of rod a month.

Design is a Joint Effort

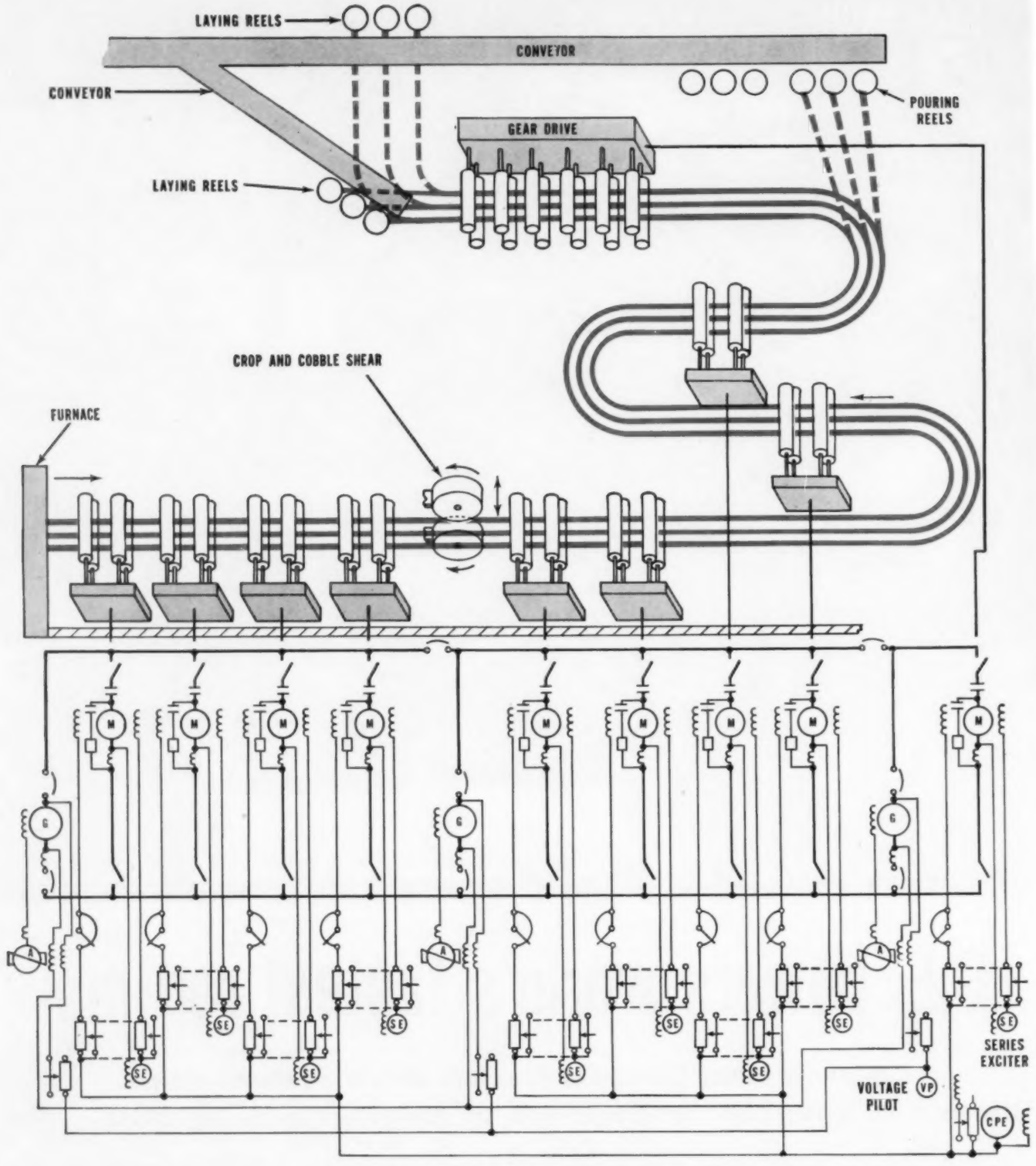
General Electric application engineers, working in close co-operation with United Engineering and Foundry Co. and J&L engineers, designed the 7200-hp main drive system. G-E field engineers assisted in the installation and start-up operations of the mill which was manufactured by United.

Modern Drives Increase Tonnage

The key to increased tonnage in today's mills is modern co-ordinated drives. Let G-E engineers help you plan your electrical system. They are specialists in the application, installation, and servicing of electric equipment for modern steel mills. Call in a G-E Apparatus Sales Representative—early in your planning. General Electric Company, Schenectady 5, N. Y.

FOR ENGINEERING DETAILS, TURN PAGE

GENERAL ELECTRIC



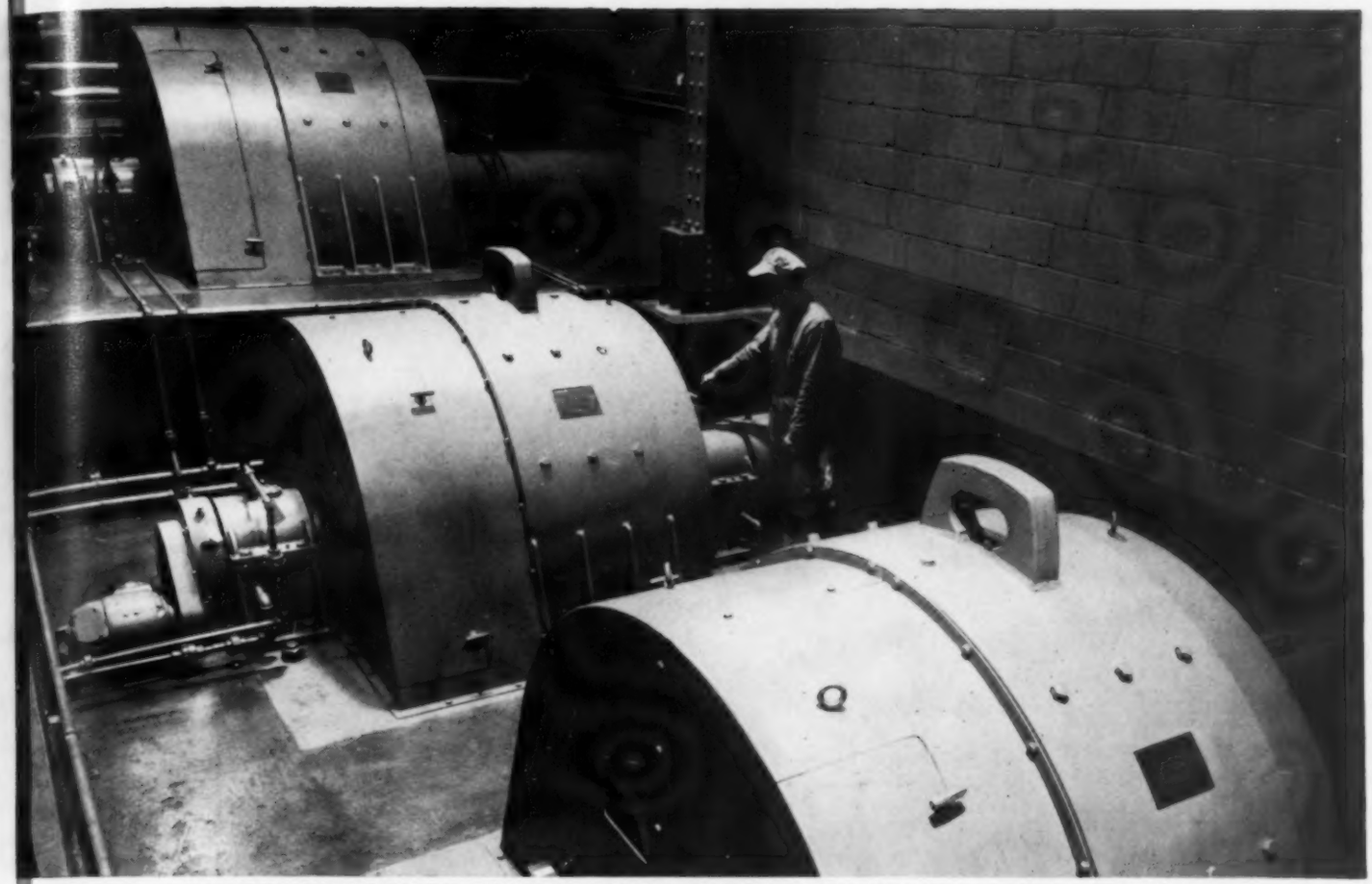
HOW THIS G-E DRIVE WORKS

This high-speed three-strand rod mill receives power from three generators—one 2250 kw and two 1500 kw, each feeding a bus section. They may be operated alone at different voltage levels, or in parallel to meet any rolling conditions. Amplidyne regulators accurately control voltage of each generator under steady-state and transient conditions. For parallel operations, amplidyne load balance between generators is connected automatically.

Nine mill motors ranging from 500 to 2000 hp deliver rod at speeds up to 5000 fpm. Low impact speed-drop characteristics of motors keep looping and stretching of rod at a minimum. Series exciters in motor auxiliary shunt fields help maintain low, steady-state speed regulation.

Adjustable voltage crop and cobble shear, pouring, and laying reel auxiliary G-E MD-600 drives are amplidyne controlled to follow speed changes in mill automatically. Rod as small as No. 4½ emit sufficient infrared light for direct operation of high-speed photoelectric relays for all relaying functions. Thus, strand indication, crop shear initiation, and rod switching are completely automatic. Complete co-ordination of main and auxiliary AC and DC control is included.

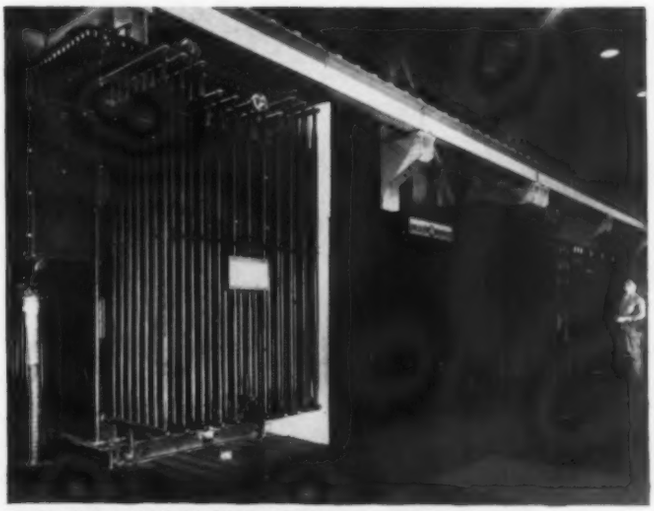
Another example of G-E Drive Engineering at work!



NINE GENERAL ELECTRIC D-C MOTORS RANGING FROM 500 TO 2000 HP POWER THE MILL'S 22 STANDS.

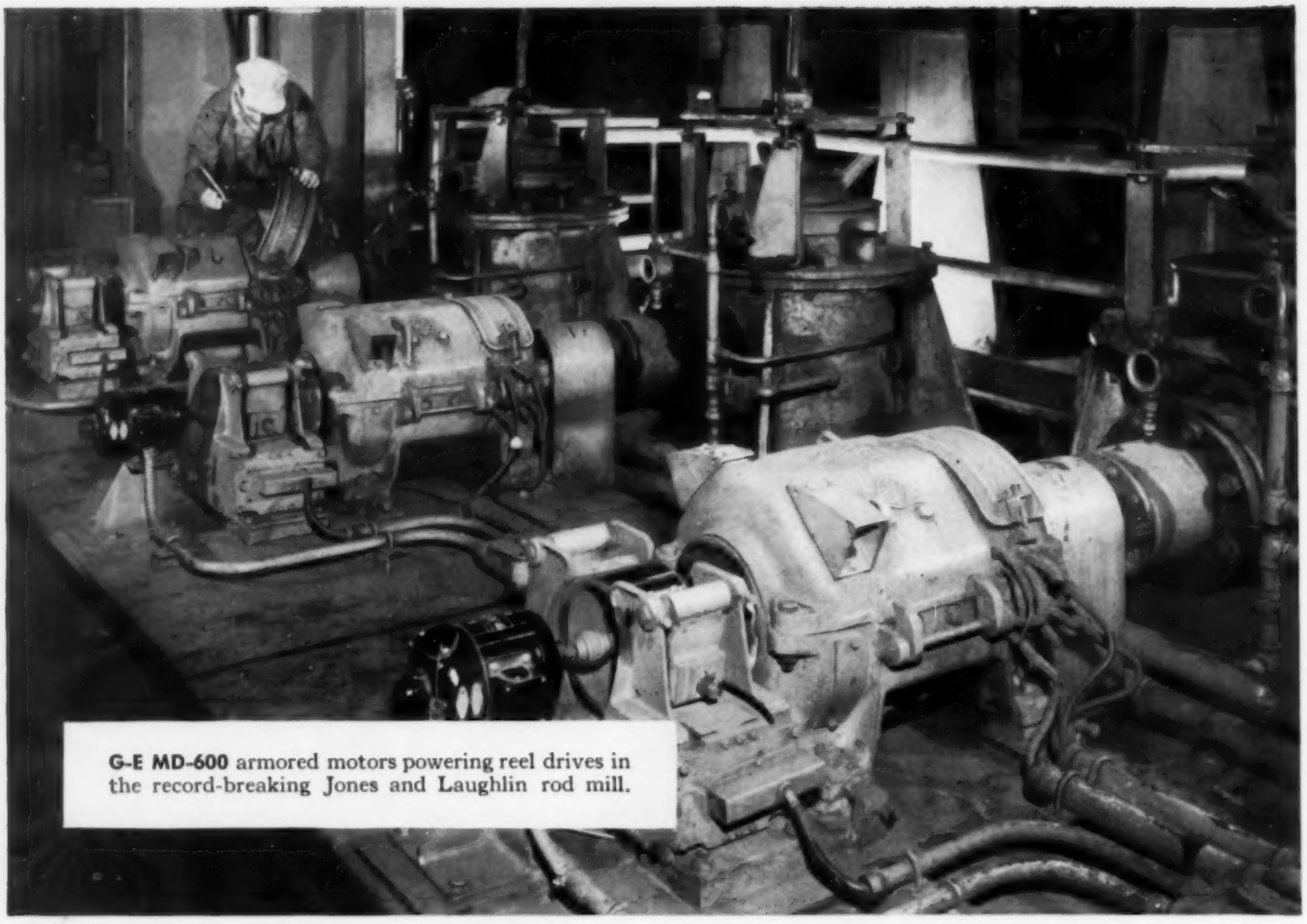
7200-hp G-E main drive system powers record-breaking J & L Rod Mill

ACCURATE CONTROL of pouring and laying reels is provided by this G-E control board. Amplidyne control assures low steady-state speed regulation of reels.



COMPACT, SPACE-SAVING G-E pumpless rectifier unit substation is easy to install. Located in motor room, it supplies d-c power to mill's auxiliary drives.

GENERAL ELECTRIC



G-E MD-600 armored motors powering reel drives in the record-breaking Jones and Laughlin rod mill.

G-E MD-600 motors help J & L step up production because . . .

Exclusive armature design of G-E armored motor allows quicker starts, stops, reversals!

The lower inertia of the MD-600 armature allows this motor to drive heavier loads, accelerate, start, stop and reverse quicker than ordinary mill motors.

G-E MD-600 armored motors start, stop and reverse quicker than ordinary mill motors because they have lower armature inertia (WK^2). For example, the MD-608 has 13% less than the next most popular mill motor.

WHY IS LOW ARMATURE INERTIA IMPORTANT TO YOU?

One important step to faster steel production is to cut manipulation time—which can take as much as half of your total production time. Manipulation time can be cut by reducing the total inertia of the machinery and auxiliary motors. Of this total inertia, your motors account for about 50%. The lower the armature inertia, the faster your motor will start, stop and reverse. The result—shorter manipulation time! By insisting on G-E MD-600 armored motors, you too can obtain faster steel production.

For more information contact your nearest G-E Apparatus Sales Office or write for a copy of Bulletin GEA-4654, Section 659-96, General Electric Co., Schenectady 5, N. Y.

GENERAL ELECTRIC

THE *New Look* IN PICKLING LINE PINCH ROLLS

Youngstown Continuous Strip Pickling Line Complete with Latest Operating Features.

F&Y

PARALLOY

REGISTERED TRADE-MARK

Eliminate

Pick up
Scratching
Galling
Chatter Marks

the rolls with uniform hardness all through, which insures maximum tonnage from new to scrap diameter.

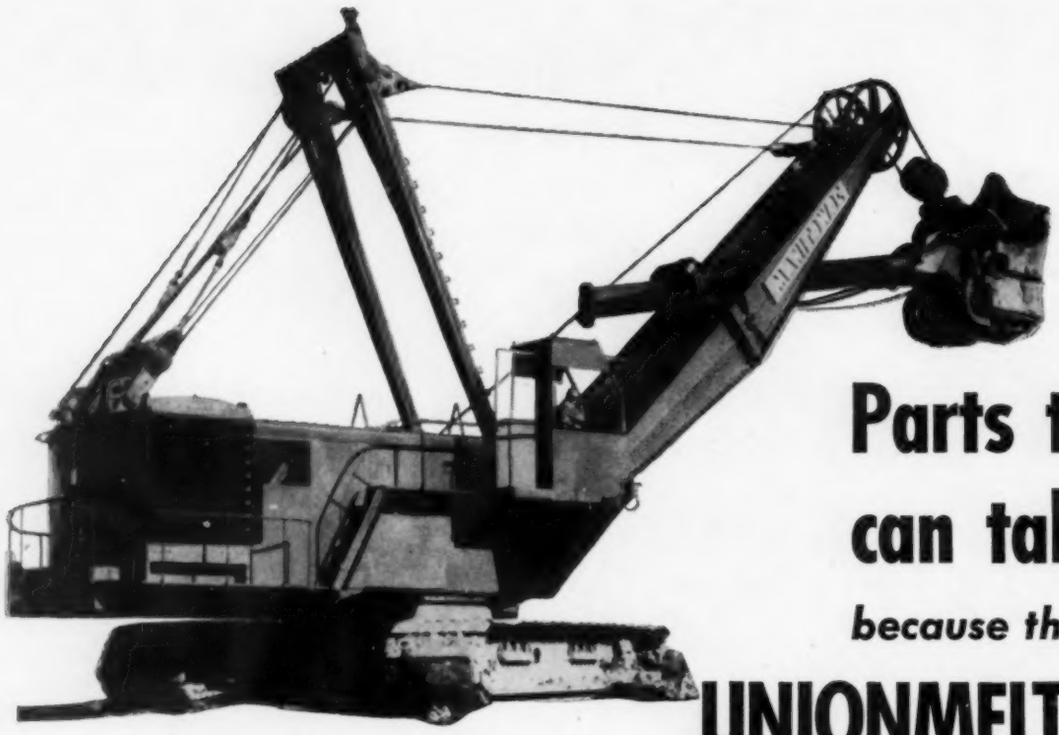
Pickle more tons between grinds with Paralloy rolls . . . Increase production and cut maintenance costs. Let our engineers quote on Paralloy pinch rolls—modernizing your present pickling line—or on a complete new pickling line.

The Youngstown Foundry & Machine Co.

OVER SIXTY YEARS OF SERVICE TO THE STEEL INDUSTRY

Youngstown, Ohio

13



Parts that can take it...

because they're UNIONMELT Welded

Dipper sticks have to be strong to absorb severe stresses. That's one reason why the three main sections of this part are UNIONMELT *welded. Sound welds can be made in metal up to 3-in. thick in a single pass.*

A power shovel dipper stick has to be strong. It must withstand severe banging, twisting, and bending stresses as its huge scoop bites out hundreds of tons of earth and rock in each day's operation. But these dipper sticks can take it—they're made by UNIONMELT welding.

Strong, clean UNIONMELT welds can be made in metals up to 3-in. thick in a single pass. There is no limit to the metal thickness that can be joined by multiple passes.

Research and years of experience have helped LINDE to develop a top notch team of fabricating processes—HELIARC, sigma, and UNIONMELT welding. For small shops or huge production lines, from carbon steel to complex alloys—there is a LINDE electric welding process to do the job. Your local LINDE representative will help you determine the best welding process for your job. Call him today for more information.

Linde
Trade-Mark

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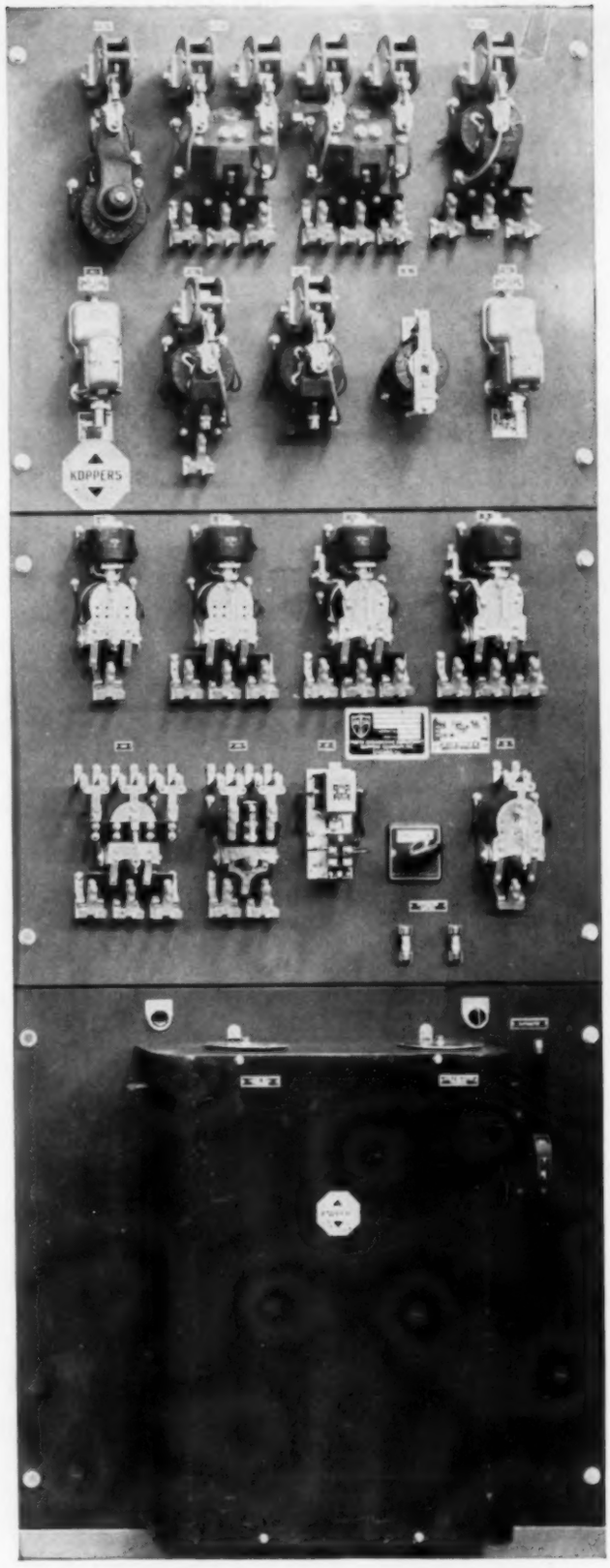

Freyn-Design BLAST FURNACE Reversing Distributor Control

AFFORDS THESE FEATURES:

1. **Coordinated, simultaneous operation of distributor and skip hoist (patented) eliminates the distributor movement as a time factor in charging.**
2. **Dynamic braking affords micrometer stopping, without drift. Shoe brakes not required and not used.**
3. **Change of rotation angle in step with the charging round (patented) eliminates the necessity of load-counting devices.**
4. **Rotation angle change after a selected number of skip loads is an available option.**
5. **Positive interlocking forces completion of distributor rotation before small bell can be opened, safeguarding against improper charging.**
6. **Extreme simplicity, easily understood control, utilizing mill-type motor supplied from constant-voltage source in common with other charging equipment. Maximum reliability.**
7. **No speed-up required to avoid delays at higher rotation angles.**
8. **The recognized standard of the industry for fourteen years, incorporating the accumulated experience of 158 installations.**
9. **Rugged—Maintenance free—Not one Freyn-Design Distributor Control has yet been worn out or replaced.**

"ASK THE MAN WHO OWNS ONE"

KOPPERS

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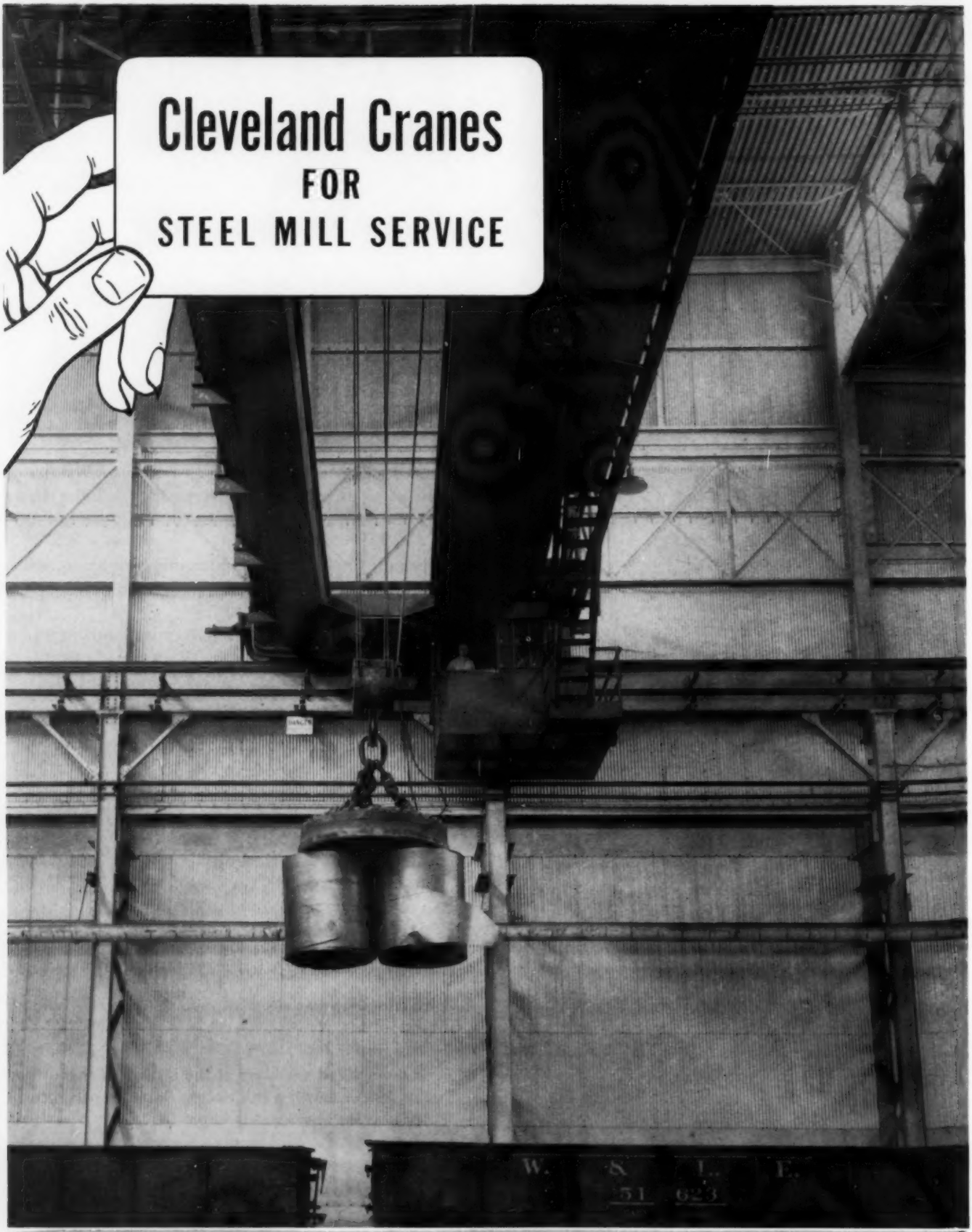
KOPPERS BUILDING • PITTSBURGH 19 *Associated with* Ashmore, Benson Pease & Co. Ltd., Stockton-on-Tees, ENGLAND; De Lattre & Finuard, Paris, FRANCE



CLEVELAND CRANES

MODERN ALL-WELDED STEEL MILL CRANES

5031 EAST 289th ST.
WICKLIFFE, OHIO

Crops and Shorts

THE 1954 Spring Conference of the Association of Iron and Steel Engineers, held in Philadelphia, Pa., May 3, 4 and 5, set a new attendance record for these meetings with a total registration of 1005. Interest was high because of the combination of fine technical sessions and the inspection trip through the Fairless Works of United States Steel Corp.

▲

ADDRESSING the dinner group at the Conference, M. W. Reed, executive vice president of raw materials and engineering of United States Steel Corp., said that engineers need a little economic and political savvy to go along with their technology, and that they have a responsibility in keeping American economy strong by helping to cut costs of products people need and by helping to develop new products and new processes.

Mr. Reed said: "We want in the engineering profession young men who regard security not as the paramount goal, but as a by-product that will surely be created by industry, by competence, by thinking big and thoroughly and by acting courageously. We want young people who will be engineers with both head and heart."

▲

WE wonder if the reason antique chairs are so uncomfortable isn't that the comfortable chairs are worn out by use.

▲

DON G. Mitchell, chairman of Sylvania Electric Products, said: "The person who talks about a recession reminds me of someone who is profoundly pessimistic because he shoots an 86 on Sunday instead of the 85 he shot on Saturday."

▲

PRODUCTION of primary aluminum hit an all-time record in the first quarter of 1954 at 698,137,342 lb.

▲

BASIC objectives advanced by the United Steelworkers wage policy committee include higher wages, improved insurance and pension plans, a guaranteed annual wage, and improved contract terms. The guaranteed wage is understood to be based on supplemental benefits to unemployment insurance set up by a trust fund.

A certificate of necessity for $70,636,000 has been issued to United States Steel Corp., covering the rebuilding of nine batteries of coke ovens at the company's Clairton plant.

▲

AVERAGE payroll costs per hour of wage employees of the iron and steel industry increased from 85.5 cents in 1940 to $2.267 in 1953, according to the American Iron and Steel Institute.

▲

ONE of our good friends says a husband is a man who wishes he had as much fun when he's out as his wife thinks he does.

▲

A report from the American Iron and Steel Institute shows that during 1953 monthly separations from the industry's payroll fluctuated between 1.9 and 3.7 per cent of employment as against a range of 3.6 — 5.2 per cent in all manufacturing.

▲

CONSIDERATION is being given by the Chicago Mercantile Exchange to steel scrap as a possible commodity to be traded on its floor. It is believed that trading in scrap futures would provide price protection, facilitate financing, and result in more economical marketing.

▲

PERHAPS the present emphasis on the social studies has some merit, but Major General Samuel D. Sturgis, Jr., chief of the Army engineers, has cited figures showing that only about 15 per cent of all public high school students take elementary algebra, and still fewer, the other preparatory mathematics.

Maybe the pendulum has swung too far.

▲

THE annual open hearth capacity of 109,094,730 net tons is based on 934 furnaces, averaging about 160 tons per heat. This compares with 990 furnaces of about 115 tons average capacity, for an annual capacity of 84,171,590 net tons in 1945.

▲

NEVER put off until tomorrow what you can do today. There may be a law against it by that time. On the other hand, someone may invent a machine to do it for you.

▲

A recent research project of the American Iron and Steel Institute has developed a specially prepared beef tallow that is an excellent substitute for palm oil in cold rolling and hot tinning. Another substitute, dimerized linoleic acid, resulted from an earlier project.

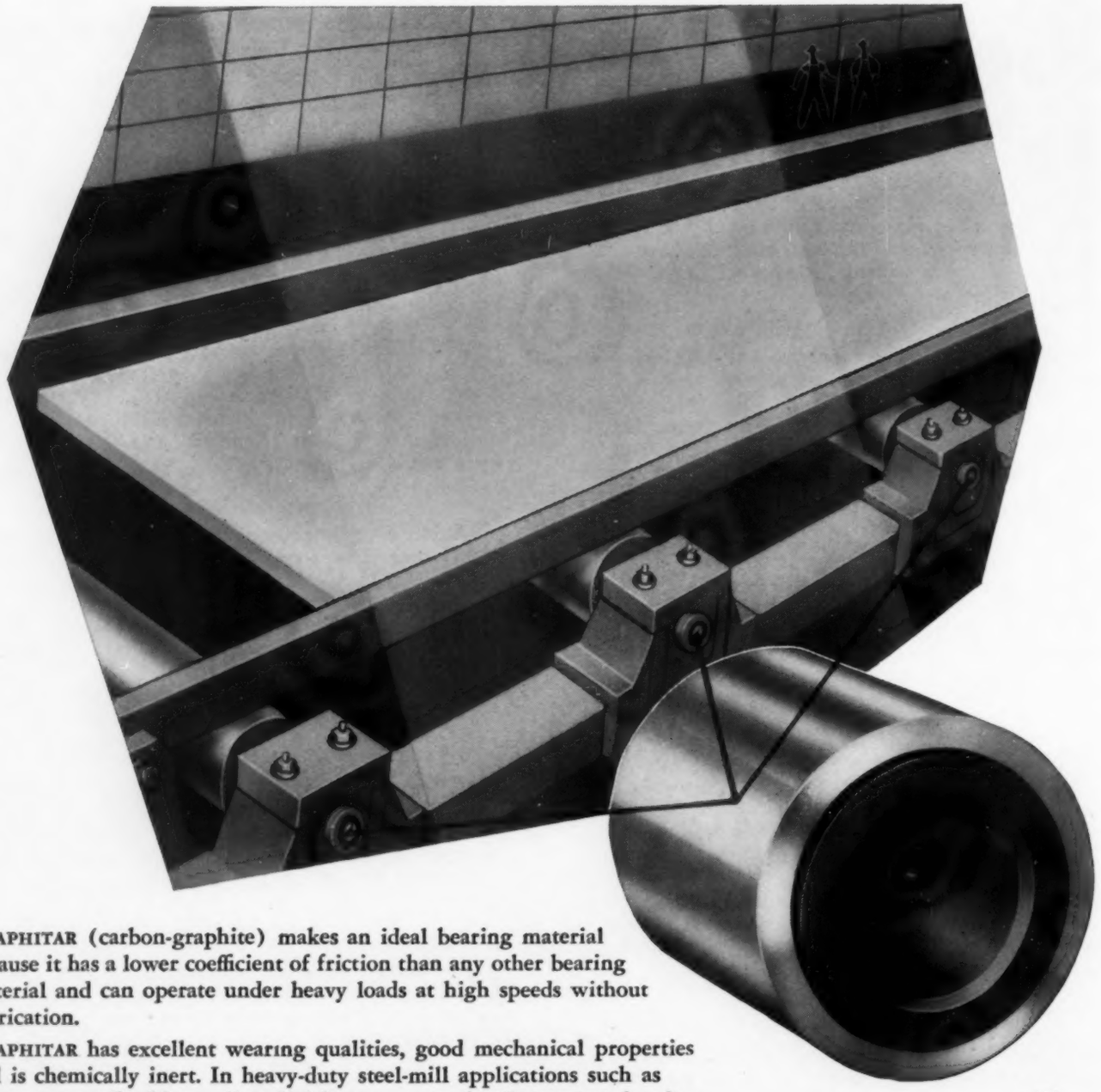
▲

COMPROMISE is a deal in which two parties get what neither of them wanted.

GRAPHITAR®

METAL-BACKED BEARINGS FOR THE STEEL INDUSTRY

Metal-backed GRAPHITAR bearings provide exceptional strength and durability for long life in difficult steel mill applications



GRAPHITAR (carbon-graphite) makes an ideal bearing material because it has a lower coefficient of friction than any other bearing material and can operate under heavy loads at high speeds without lubrication.

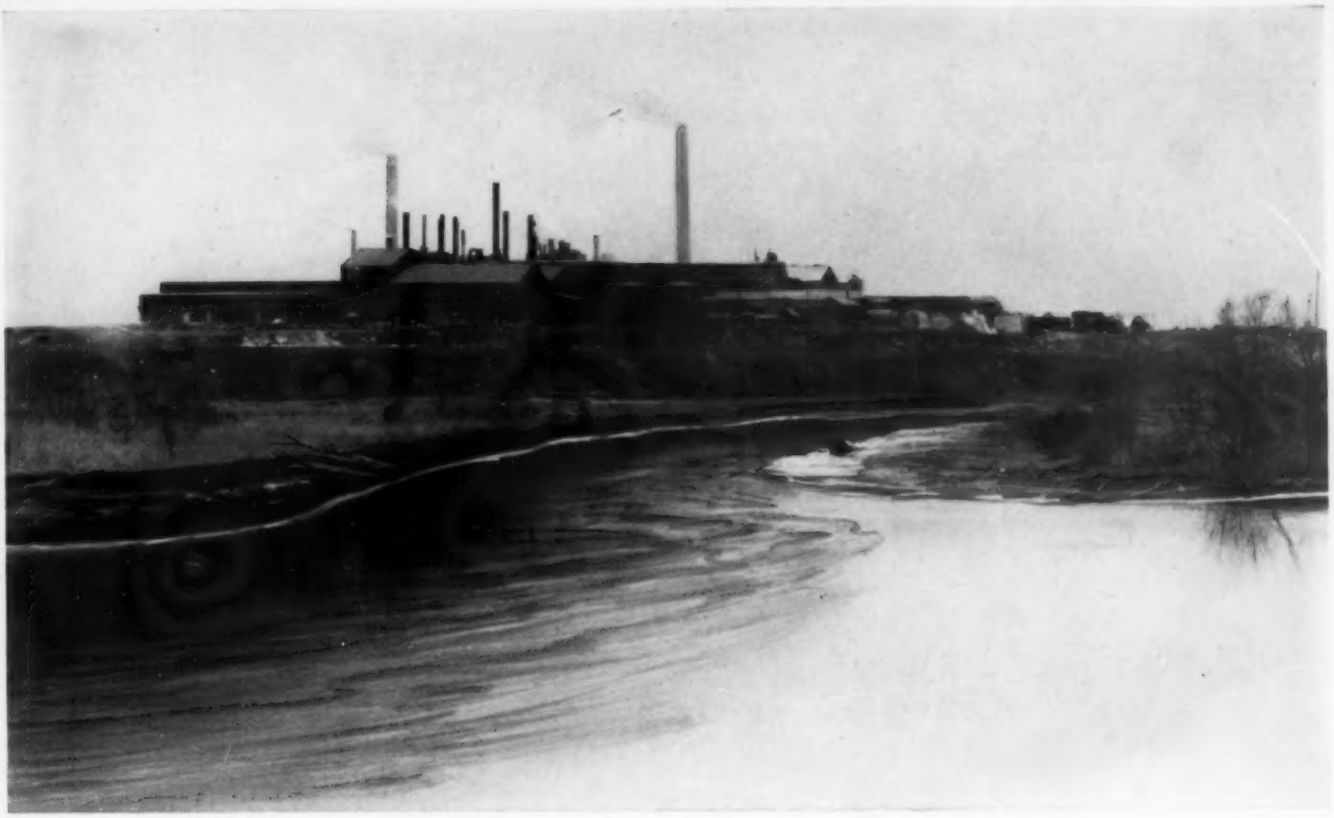
GRAPHITAR has excellent wearing qualities, good mechanical properties and is chemically inert. In heavy-duty steel-mill applications such as shear or cut-off tables, coil and slab conveyors, the GRAPHITAR bearings are metal-backed to provide additional strength and resistance to shock. GRAPHITAR metal-backed bearings can be supplied in tolerances as close as .0005" ready for installation.

183

OUR 100th YEAR

THE UNITED STATES GRAPHITE COMPANY

DIVISION OF THE WICKES CORPORATION • SAGINAW, MICHIGAN



WORRIED ABOUT WASTE DISPOSAL?

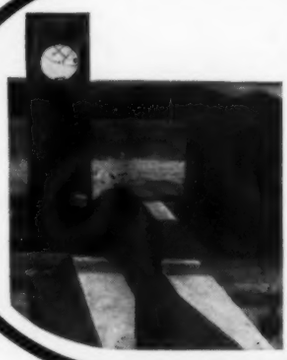
Bailey Meters Help you to Reduce Pollution

● The disposal of industrial wastes without stream pollution calls for careful planning and continuous vigilance.

That's where Bailey Meters and Controls come in. We measure the flow and pH of sewage, sludge, and industrial wastes flowing in open channels or pipe lines. These and other factors, such as levels, rates of chemical feed, and flow of air, may be co-ordinated into a completely automatic system for the treatment and disposal of waste materials.

When you want fast, complete and authoritative answers to the measurement and control aspects of your waste disposal problems, reach for your phone and call your local Bailey Engineer. Offices in all principal industrial centers.

P-24



BAILEY
OPEN CHANNEL METERS

These indicating, recording and integrating meters are suitable for measuring industrial wastes, sewage, sludge, corrosive liquids, and irrigation water flowing in all types of open channel primary metering devices, such as Venturi flumes, weirs, or nozzle flumes. Electric or pneumatic telemetering permits location of receivers wherever desired. Ratio of flows and chemical feeds may be controlled automatically.

BAILEY METERS

BAILEY METER COMPANY

1047 IVANHOE ROAD
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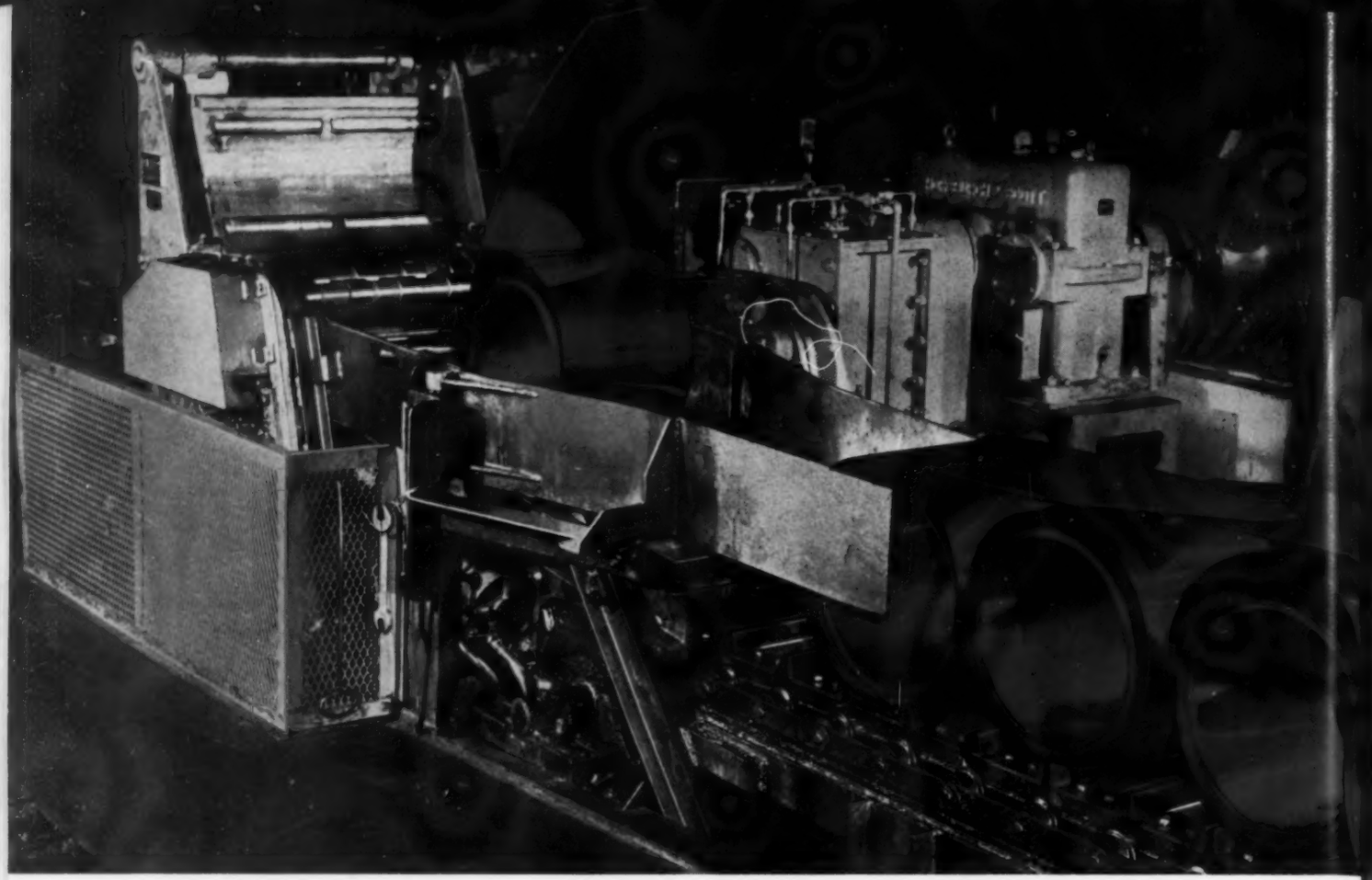
Process Controls
TEMPERATURE · FLOW
PRESSURE · LEVEL
GAS ANALYSIS · RATIO



New BLISS coiler makes light work of heavy gage brass

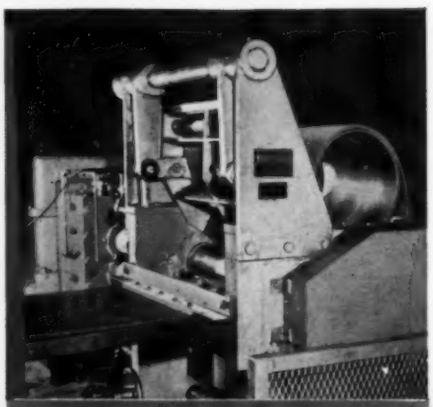
Enables American Brass Company to reduce costs and increase production on certain operations

Ever alert to reduce manufacturing and handling costs, The American Brass Company installed a new Bliss upcoiler in their Waterbury, Connecticut plant. It replaced equipment which could not coil brass or nickel silver alloys heavier than 0.280" gage. This meant that long unwieldy bars—up to 30 feet—had to be carried back to the sticking side of the mill in a costly transfer operation for additional passes to suit the coiler limitations.

With the new Bliss upcoiler, however, 0.400"-gage brass and silver alloys are coiled in widths up to 25 inches. Important savings in machine time and handling costs have been achieved.

The trend to heavier coilers can be observed throughout the metal-producing industry. For example, in addition to the installation at Waterbury, Bliss has supplied American Brass Company with three other duplicate design coilers for its Ansonia, Kenosha and New Toronto plants.

Modern coilers and other material-handling equipment are described and illustrated in Bliss' newly-revised 60-page brochure. Write today for your copy of Catalog 40-A.



THREE-ROLL PYRAMID-TYPE UPCOILER is of rugged, functional construction. Capacity: up to 0.4375" thickness and to widths of 28" on certain mild metals. Straight tailing feature is provided to produce flat "sticking ends" for subsequent passes.

Remember: BLISS SINCE 1857 **for Presses, ROLLING MILLS, Special Machinery**

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ROLLING MILL DIVISION: SALEM, OHIO

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Iron and Steel ENGINEER

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In This Issue

Patent Reviews — By Melvin Nord, Patent Attorney, Detroit, Mich..... 23
A New Theory of Hot Rolling — By George S. Mican, Division Superintendent — Structural, South Works, United States Steel Corp., Chicago, Ill..... 55
The Electric Furnace West of the Rockies — By W. B. Wallis, President, Pittsburgh Lectromelt Furnace Corp., Pittsburgh, Pa..... 80
Estimating Motor Room Installation Costs — By Wray Dudley, Chief Consulting Engineer, Patterson-Emerson-Comstock, Inc., Pittsburgh, Pa. 87
Application of Bronze Bearing Alloys — By James L. Duchene, National Bearing Division, American Brake Shoe Co., Pittsburgh, Pa..... 92
Crane Power Limit Switches — By R. W. Graham, Superintendent, Electrical Dept., Bethlehem Steel Co., Lackawanna, N. Y..... 98
A Safety Limit Stop — By R. J. Harry, Vice President Alliance Machine Co., Alliance, Ohio..... 104
Current AISE District Section Meeting Notices..... 108
New Soaking Pit Facilities at Steel Division of Ford Motor Co. — By B. D. Barns, Supervisor and H. E. Raaflaub, Senior Fuel and Utilities Engineer, Fuel and Utilities Dept., Steel Division, Ford Motor Co., Dearborn, Mich..... 109
Problems in Developing Alloy Steels for Aircraft Gas Turbines — By F. L. Ver Snyder, Thomson Laboratory, General Electric Co., Lynn, Mass. 115
AISE Spring Conference Pictorial Review — 1954..... 124
Adjustable Voltage Coal Bridge Installed at Steel Co. of Canada — By W. G. Wright, Application Engineer, Canadian General Electric Co., and D. C. McCrady, Electrical Superintendent, Steel Co. of Canada, Ltd., Hamilton, Ontario, Canada..... 126
Power Generation Expansion — By Harold I. Howell, System Project Engineer, Niagara Mohawk Power Corp., Buffalo, N. Y..... 132
New Process Developed to Form Metals..... 137
Pittsburgh Steel Completes Cold Mill Facilities..... 141
U. S. Steel Unveils New Coal Mining Machine..... 145
Tips on Battery Room Layout — By K. A. Vaughan, Manager, Field Engineering, Gould-National Batteries, Inc., Trenton, N. J..... 148
Date-Line Diary..... 159
Industry News..... 175
Personnel News..... 197
Publication Service..... 209
Equipment News..... 219
Index to Advertisers..... 231

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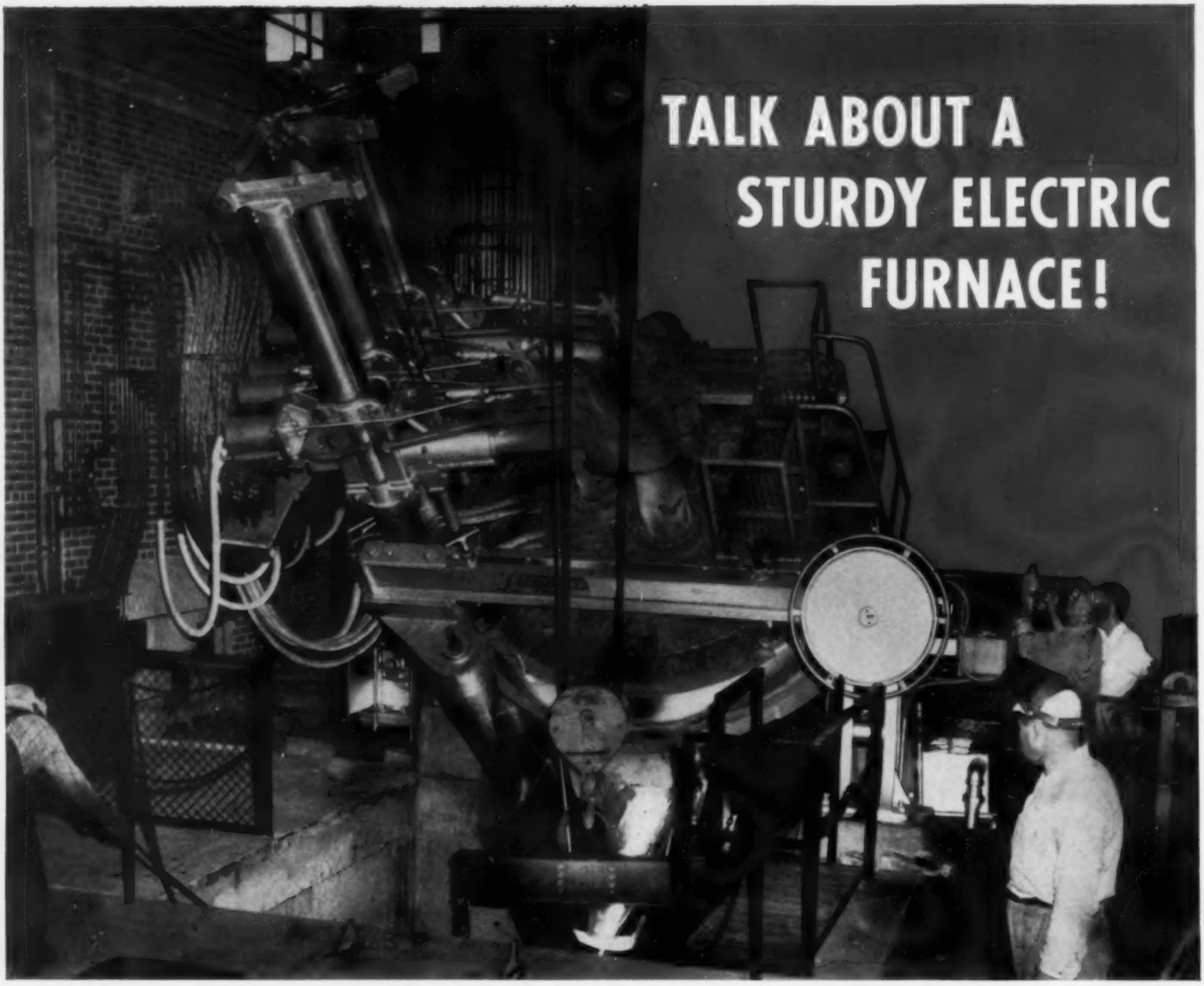

"Our old Lectromelt takes the power overload of an oversize transformer without a sign of strain to the furnace or its parts."—Duncan Foundry, Alton, Illinois

Look at the record of Duncan Foundry's durable Lectromelt*

In October 1952, this test was made on their 1½-ton per hour Lectromelt: The furnace operated steadily for 27 days, 24 hours per day, using an oversize, 2000-kva transformer. 578 heats were tapped for an average of 21.4 heats per day. Average charge per heat was 6688 lbs. Time from power-on to tap averaged 58.5 minutes per heat. Time from tap to power-on for next heat averaged 8.8 minutes. Average power consumption per ton of metal was 501 kwh.

Duncan's oversize transformer keeps metal pouring fast, but throws a jolting overload of power into the furnace to do it. Still operating under this maximum stress, their sturdy Lectromelt turns out daily heats without a sign of extra strain or wear.

Expanding recently, Duncan Foundry added another, larger Lectromelt Furnace, confident of its quality and durability.

Look for your new electric in Lectromelt's Furnace line. Write for Bulletin No. 9, describing these versatile melting, smelting, refining and reduction furnaces. Write Pittsburgh Lectromelt Furnace Corporation, 310 32nd Street, Pittsburgh 30, Pennsylvania.

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*REG. T. M. U. S. PAT. OFF.

MOORE RAPID

WHEN YOU MELT... *Lectromelt*

A NEW THEORY OF HOT ROLLING

By GEORGE S. MICAN
Division Superintendent — Structural
South Works
United States Steel Corp.
Chicago, Ill.

. . . . the following paper may well become a classic in the theory of rolling . . . .

▲ KNURLED rolls were placed in service in a 44-inch slabbing mill to determine whether an interrupted roll surface would retard the development of surface tears in the slabs in rolling. When after a short trial it was evident that surface tearing was retarded by the knurling, it was initially assumed, in conformance with prevailing theories, that the detrimental effects of an increased coefficient of friction were more than offset by the induced interrupted surface in the same manner as mold corrugations are assumed to retard ingot cracks. When the operating results for a calendar year were compared with those of prior years, and it was evident not only that the tearing tendency was reduced but also that roll wear, roll breakage, and power consumption were reduced, an analysis was undertaken with the purpose of deriving a plausible explanation. This analysis developed into what may be considered a new theory of hot rolling.

	Inches of roll diam used	Net tons of product rolled	Tons per inch	Kwhr per ton
Plain rolls	36½	3,504,000	96,200	12.21
Knurled rolls	7⅝	1,875,900	246,000	11.21

A theory may be defined as a plausible or scientifically acceptable general principle offered to explain some particular phenomena. A new theory is justified only if it provides a more accurate qualitative and quantitative explanation than was afforded by prior theories. Theories of rolling are interpreted quantitatively in the form of rolling pressure diagrams that are derived in accordance with stated principles.

The principles which constitute the author's theory of hot rolling may be summarized in the following three paragraphs:

1. A new method for the construction of hot rolling pressure diagrams is derived. Base curves for non-cumulative horizontal pressure effects are derived from an application of the shear stress theory. Cumulative horizontal pressure effects are superimposed on the base curves by applications of modified Prandtl equations. Limiting values of the pressure envelopes are established by the application of modified Prandtl equations which conform to the criteria of plastic yielding.
2. Contrary to prior concepts, when all other rolling conditions are held constant, progressive incremental increases in the coefficient of friction in the approximate value range of 0.3 to 0.55 result in incremental decreases in rolling pressures and decreasing trends for roll wear, roll breakage, power consumption, and surface tears of the rolled material. Incremental increases in the coefficient of friction in the range greater than the approximate 0.55 value result in the rolling pressure and related effects remaining constant at the minimums attained at the 0.55 value.
3. When all other rolling conditions are held constant, progressive increases in roll diameters result in progressively increased rolling pressures in general conformance with prior concepts. Trends for the surface tearing of the rolled material, however, decrease progressively with incremental increases in roll diameters.

In a comprehensive summary of the literature on the subject, Underwood[1]* recognized the theories of Siebel [2], Von Karman[3], and Orowan[4] as basic theories of rolling. Siebel introduced the concept of the friction hill; Von Karman the concept of the cumulative effect of horizontal pressures; Orowan the concept of inhomogeneous deformation. The quantitative results derived from Siebel's theory are considered too low by reason of the omission of cumulative horizontal pressure effects. It is generally recognized that the theories of Von

*Numbers refer to corresponding references in the Bibliography at end of article.

Karman and Orowan are the best developed to date for qualitative and quantitative applicability to the cold rolling of thin sheet and strip, but are quantitatively inapplicable to hot rolling. Whereas the principles developed in this work are applied quantitatively to hot rolling, it is recognized that the final determination of the merit and the range of such applicability is subject to a broader range of test than can be covered in this single work.

The hot rolling process is essentially a plastic deformation process in which elastic deformation may be considered negligible. Steel at hot rolling temperatures is a metallic polycrystalline aggregate of random grain orientation and of sufficient grain fineness to behave during deformation as a homogeneous isotropic body. The basic mechanism of deformation is a crystallographic slippage which begins in grains most favorably oriented in the direction of the maximum shear stress, and progresses to all other grains so that outwardly the deformation appears to be uniform. The relative plasticity of a material is its relative capacity to form slip planes along which displacements can take place without destruction of atomic cohesion. For the existence of the plastic condition in a body, its resistance to the formation of slip planes must be overcome by the imposed stress. For the hot rolling process, the basic characteristic of plasticity is the relation between the imposed load per unit of area (stress) and the extent of deformation per unit of volume (strain) within the range of local and general indestructibility of the material by fracture.

In the development of the subject matter, the equations used in the construction of the quantitative pressure diagrams are first derived. For the benefit of interested rolling mill operators, the derivations are shown in more detail than is customary in the literature on the subject. The method of construction of the pressure diagrams is then explained, and subsequent illustrations depict the relationship between varying coefficients of friction and resulting rolling pressures for a wide range of rolling conditions. Several comparisons of theoretical pressure diagrams with actual pressure recordings made at the Kaiser Wilhelm Institute are indicated. Specific application of the theory to actual slabbing mill rollings is given. The concluding portion of the work develops the relation between varying roll diameters, power consumption, and surface tearing tendencies.

STRESS CONDITION FOR THE PLASTIC STATE

Mohr[5] utilized the stress sphere to resolve the combined stresses acting on a body into three principal stresses designated as S_1, S_2, and S_3, acting in the direction of three coordinate reference axes X, Y, and Z, and three principal shearing stresses τ_1, τ_2, and τ_3, making angles of 45 degrees with the sections across which the principal stresses act, where:

$$\tau_1=\frac{S_2-S_3}{2},\ \tau_2=\frac{S_3-S_1}{2},\ \tau_3=\frac{S_1-S_2}{2}$$

$$\tau_1+\tau_2+\tau_3=0$$

The shear stress theory is based on the hypothesis that the maximum shear stress in a body is equal to one half of the difference between the maximum and the minimum principal stresses, is independent of the magnitude of the intermediate stress, and results in the inception of the plastic state when it becomes equal to the deformation strength of the material. If the principal stresses S_1, S_2, and S_3 are arranged in sequence from $+\infty$ (tension) to $-\infty$ (compression), the shear stress theory may be expressed mathematically in the following forms:

$$\frac{S_1-S_3}{2}=\tau_v \quad \text{(1a)}$$

where τ_v is a variable shear stress induced in the body by a combined externally applied stress. The shear stress τ_v attains a maximum value τ_{vm} when the magnitude of the applied stress results in the inception of plastic flow in the body. Then Equation (1a) becomes:

$$\frac{S_1-S_3}{2}=\tau_{vm}=\text{Deformation strength} \quad \text{(1b)}$$

If the body is subjected to simple tension and yields plastically when the tensile stress is S, then substituting $S=S_1$ and $S_3=0$ in Equation (1a), the equation becomes:

$$S=2\tau_{vm}=2\tau_c \quad \text{(1c)}$$

where τ_c is a constant and the expression states that the yield stress in simple tension is equal to two times the yield stress in simple shear. The same expression is attained when the body is subjected to simple frictionless compression and yields plastically when the compressive stress is S. For this condition, substituting $S=S_3$ and $S_1=0$ in Equation (1a), the equation again becomes $S=2\tau_{mc}=2\tau_c$.

$$\therefore\ S_1-S_3=S=\text{Criterion for plastic yielding} \quad \text{(1d)}$$

where S is the yield strength of the material at the inception of plastic flow in simple tension and frictionless compresson and is a constant for the material at any given hot working temperature. For convenience, the foregoing definition of S is abbreviated to "compressive strength" in subsequent references.

The deformation strength of a material at any given hot working temperature is equivalent to the maximum shear stress induced in the body at the inception of plastic yielding by the combined stresses acting on the body. Figure 1 is in essence a graphic illustration of the shear stress theory based on Mohr's plane representation of the limiting stress conditions of a plastic material. As illustrated, an infinite variety of stress conditions can induce the plastic state because either of the two principal stresses S_1 and S_3 may assume any value, whereby the other is so determined in the region of flow that the condition of Equation (1b) is satisfied. As further illustrated, the ordinate to the enveloping curve, representing both the maximum shearing stress and the deformation strength, is not a constant for any material, but varies with the condition of stress which reflects the method of imposed deformation.

A three-dimensional stress diagram would be required to represent cold working, since compressive strength varies with the degree of cold work. Since this effect is absent in hot working, the plane representation is

applicable as an approximation. Consideration of variations of compressive strength with temperature drop in the pass as well as other influencing variables in hot rolling are reserved for later consideration.

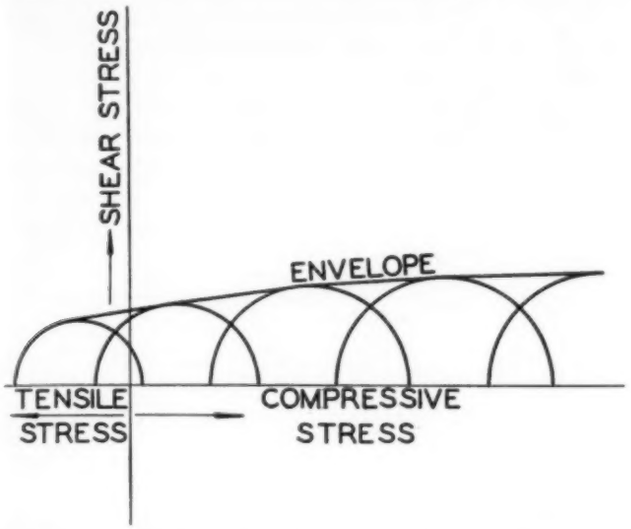


Figure 1 — Mohr's plane representation of the limiting stress conditions of a plastic material.

MATHEMATICAL SYMBOLS AND ABBREVIATIONS

α = Angle of contact between the material and the rolls.

β_1 = Apparent neutral angle = Angle between the line of roll centers and the radius to the no slip point as derived from Siebel's graphical construction.

β_2 = Neutral angle = Angle between the line of roll centers and the radius to the no slip point as derived from the base curve of unit stress.

$\beta_3 - \beta_4$ = Angle between the radii to the intersections of the arc of contact with two vertical planes which are located respectively on the entry and the delivery side of the neutral plane, and which have equal and opposite horizontal forces acting on them as the result of noncumulative frictional effects.

β_3 = Angle between the line of roll centers and the radius to the intersection of the arc of contact with the vertical bounding plane on the entry side of the neutral plane, referred to in the $\beta_3 - \beta_4$ angle definition.

β_4 = Angle between the line of roll centers and the radius to the intersection of the arc of contact with the vertical bounding plane on the delivery side of the neutral plane, referred to in the $\beta_3 - \beta_4$ angle definition.

θ = Variable angle between the line of roll centers and the radius to any point on the arc of contact.

θ_m = Angle between the line of roll centers and the vertical center line between the vertical planes at angles β_3 and β_4.

θ_A = Angle between the line of roll centers and the radius to the midpoint of the arc of slippage on the entry side of the neutral plane.

f = Friction angle expressed in radians.

ρ = Angle whose tangent is equal to μ.

μ = Coefficient of friction between material and rolls.

$\mu_s = \mu$ which results in sticking over entire roll arc.

R = Radius of roll.

$W = R \sin \alpha$ = Horizontal projection of arc of roll contact and equivalent die width.

$h = R(\sin \beta_3 - \sin \beta_4)$ = Horizontal distance between the vertical $\beta_3 - \beta_4$ bounding planes.

h_1 = Height of stock at entry plane.

h_2 = Height of stock at delivery plane.

h_3 = Height of stock at angle β_3 from the line of roll centers.

h_4 = Height of stock at angle β_4 from the line of roll centers.

h_θ = Height of stock at angle θ from the line of roll centers.

L = Vertical distance from the horizontal center line of the stock to the roll arc as determined on a vertical center line between the vertical planes at angles β_3 and β_4.

l = Length of arc of slippage on the entry side of the neutral plane.

x = Variable horizontal distance from the entry to the neutral plane and correspondingly from the delivery to the neutral plane.

y = Variable horizontal distance from the midpoint of h to either one of the two vertical planes a angles β_3 and β_4.

H_D = Net horizontal force of one roll acting in the delivery plane direction.

H_E = Net horizontal force of one roll acting in the entry plane direction.

P = Radial unit roll pressure.

P_A = Average radial roll pressure over the length of the arc of slippage on the entry side of the neutral plane.

P_V = Vertical component of radial unit roll pressure.

S = Compressive strength of the material.

$S_{1D\theta}$ = Vertical unit stress between the entry and the neutral planes at angle θ.

$S_{1E\theta}$ = Vertical unit stress between the neutral and the delivery planes at angle θ.

$S_{3D\theta}$ = Horizontal unit stress between the entry and the neutral planes at angle θ.

$S_{3E\theta}$ = Horizontal unit stress between the neutral and the delivery planes at angle θ.

S_{3E} = Horizontal unit stress on the vertical plane at angle β_3.

S_{3D} = Horizontal unit stress on the vertical plane at angle β_4.

$S_3' = \frac{S_{3D} + S_{3E}}{2}$ = Average horizontal unit stress on the vertical planes at angles β_3 and β_4.

q = Variable vertical unit stress at a variable distance from the vertical center line of the compressing platens in the basic Prandtl equation.

q_m = Maximum vertical unit stress developed on the vertical center line of the compressing platens in the basic Prandtl equation.

t = Variable horizontal stress developed at the edge of the material at a variable vertical distance from the horizontal center line of the compressed material in the basic Prandtl equation.

Q_m = Twice the magnitude of S_3' in the modified Prandtl equation.

T_R = Variable cumulative radial unit pressures at the roll arc resulting from the horizontal unit stresses acting on the vertical planes at angles β_3 and β_4 as determined by solutions of the modified Prandtl equation.

T_V = Vertical component of T_R.

S_1, S_2, S_3 = Three mutually perpendicular principal normal stresses acting in the direction of the coordinate axes X, Y, and Z, into which any complex state of stress at a point in a body can be resolved.

τ_1, τ_2, τ_3 = Three mutually perpendicular shearing stresses acting at an angle of 45 degrees with the sections across which the principal stresses act.

$\tau_v = \frac{S_1 - S_3}{2}$ = Variable shear stress dependent on the relative magnitudes of the maximum and the minimum principal stresses.

$\tau_{vm} = \frac{S_1 - S_3}{2}$ = Deformation strength when the shear stress attains a maximum value at the inception of plastic yielding of the material under the imposed combined stress.

$\tau_c = \frac{S}{2}$ = Shear stress in simple tension and frictionless compression at the inception of plastic flow. The value is a constant for a given material at a given hot working temperature.

$\frac{h_1}{W}$ = Ratio of initial height of stock to horizontal projection of arc of contact (equivalent die width).

$\frac{P}{S}$ = Ratio of unit radial roll pressure to compressive strength.

$\frac{P_V}{S}$ = Ratio of vertical component of unit radial roll pressure to compressive strength.

$\frac{T_R}{S}$ = Ratio of cumulative unit radial roll pressure as determined by modified Prandtl equation to compressive strength.

$\frac{T_V}{S}$ = Ratio of vertical component of cumulative radial roll pressure as determined by modified Prandtl equation to compressive strength.

V_1 = Velocity of stock at entry plane in feet per second.

V_2 = Velocity of stock at delivery plane in feet per second.

DERIVATION OF THE BASE CURVE EQUATIONS

One of the first and simplest theories of rolling was proposed by E. Siebel and has become known as "The Theory of the Friction Hill." Siebel's basic equations for noncumulative horizontal forces can be converted into integrable forms. His general indication of the application of the shear stress theory for the determination of radial pressures can also be converted into quantitative equations for the determinations of unit radial stresses in terms of compressive strengths, resulting from the non-cumulative portions of horizontal forces. The conversions indicated are the basis of the derivation of the base curve equations for the pressure diagrams in this work.

The following assumptions are common to both the Siebel and the Von Karman theories:

1. The material does not spread laterally. This condition is approximately satisfied if the thickness of the material is small compared with its width.
2. The coefficient of external friction μ between the material and the rolls is constant at all points in the arc of contact.
3. Plane sections of the material before rolling, remain plane during rolling.
4. There is no elastic deformation of the rolls in the arc of contact.
5. The elastic deformations of the material are negligible in comparison with the plastic deformations, and the material is homogeneous.
6. The criterion of plastic yielding $S_1 - S_3 = S$ holds for the material rolled and for the conditions of rolling.
7. The compressive strength S is constant throughout the contact length. In hot rolling, the change in compression rate from point to point along the arc of contact has no effect on the magnitude of S.
8. The peripheral velocity of the rolls is uniform, i.e., that the rolls are neither accelerating nor decelerating.

Referring to Figure 2, the vertical plane through the initial points of contact between the material and the rolls is designated as the entry plane. The vertical plane through the final points of contact between the material and the rolls is designated as the delivery plane and is coincident with the line of roll centers.

For a condition of slippage between the rolls and the material throughout the arc of roll contact, there is only one point in the arc of roll contact at which the surface velocity of the material and the peripheral velocity of the rolls are equal. This is the neutral point, and the angle from the neutral point to the delivery plane is the neutral angle. The vertical plane through the neutral points is designated as the neutral plane. The velocity of the material surface relative to the roll surface constitutes a backward slip between the entry and the neutral planes, and a forward slip between the neutral and the delivery planes.

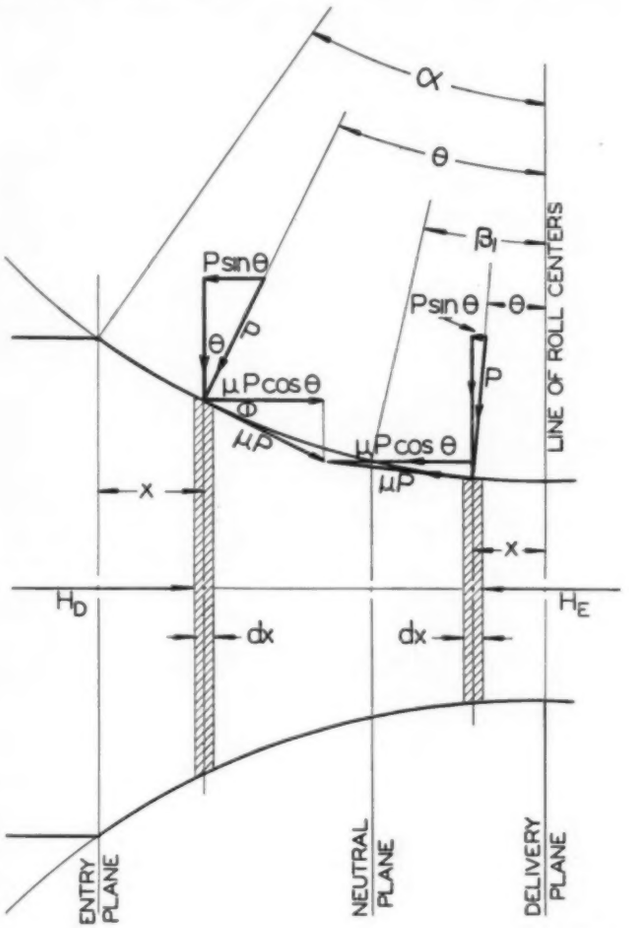


Figure 2 — Resolution of stresses acting on elemental cross sections within the arc of roll contact for the purpose of determining horizontal forces without cumulative effects.

When the elemental areas shown in Figure 2 are of unit length in the direction perpendicular to the plane of the paper, and the symbols and abbreviations shown in the preceding section are used, from a consideration of the forces of one roll, acting on those areas:

$$dH_D = \frac{dx}{\cos\theta} \cdot \mu P \cos\theta - \frac{dx}{\cos\theta} \cdot P \sin\theta$$

$$= \mu P \cdot dx - P \tan\theta \cdot dx$$

$$= P(\mu - \tan\theta)dx$$

$$= P(\tan\rho - \tan\theta)dx$$

$$H_D = P\int_0^x (\tan\rho - \tan\theta)dx \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$dH_E = \frac{dx}{\cos\theta} \cdot \mu P \cos\theta + \frac{dx}{\cos\theta} \cdot P \sin\theta$$

$$= \mu P \cdot dx + P \tan\theta \cdot dx$$

$$= P(\mu + \tan\theta)dx$$

$$= P(\tan\rho + \tan\theta)dx$$

$$H_E = P\int_0^x (\tan\rho + \tan\theta)dx \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Siebel showed by a graphical construction, Figure 3, that the relative magnitudes of horizontal forces at various points on the arc of roll contact are equivalent to the vertical distances between arc AED and lines AFC and CD which slope at angle ρ with the horizontals through points A and D. This same construction has been used for the mathematical determination of the neutral angle and the location of the neutral plane. In this work β_1 is designated as the apparent neutral angle.

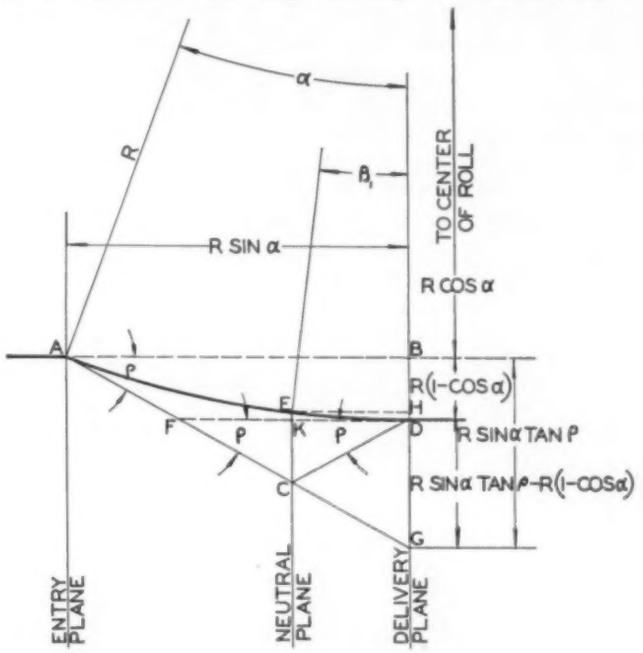


Figure 3 — Siebel's graphical representation of the relative magnitude of horizontal forces acting within the arc of roll contact and the basis for the determination of the apparent neutral angle β_1.

$$AB = R \sin\alpha$$

$$BD = R(1 - \cos\alpha)$$

$$\tan\rho = \frac{BG}{R \sin\alpha}$$

$$BG = R \sin\alpha \tan\rho$$

$$DG = R \sin\alpha \tan\rho - R(1 - \cos\alpha)$$

Since FD = 2 KD = 2 EH,

$$\frac{DG}{BG} = \frac{2\,EH}{R \sin\alpha} = \frac{R \sin\alpha \tan\rho - R(1 - \cos\alpha)}{R \sin\alpha \tan\rho}$$

$$EH = \frac{R \sin\alpha \tan\rho - R(1 - \cos\alpha)}{2 \tan\rho}$$

$$\sin\beta_1 = \frac{EH}{R} = \frac{\sin\alpha}{2}\left[1 - \frac{(1 - \cos\alpha)}{\tan\rho \sin\alpha}\right] \quad \ldots\ldots (4)$$

In order to integrate Equations (2) and (3) it is necessary to transform them into terms of a single variable for which finite values may be substituted:

$$H_D = P\int_0^x (\tan\rho - \tan\theta)dx$$

$$= P\int_0^x \tan\rho\, dx - P\int_0^x \tan\theta\, dx$$

Since $x = W - R\sin\theta = R(\sin\alpha - \sin\theta)$

Then $dx = -R\cos\theta\, d\theta$

$$P\int_0^x \tan\rho\, dx = P \cdot x \cdot \tan\rho$$

$$= P \cdot R \cdot \tan\rho\,(\sin\alpha - \sin\theta)$$

$$P\int_0^x \tan\theta\, dx = -P\int_\alpha^\theta \tan\theta\, R\cos\theta\, d\theta$$

$$= -P \cdot R \cdot \int_\alpha^\theta \sin\theta\, d\theta$$

$$= -P \cdot R\Big[(-\cos\theta)\Big]_\alpha^\theta$$

$$= -P \cdot R(-\cos\theta + \cos\alpha)$$

$$= P \cdot R(\cos\theta - \cos\alpha)$$

$$\therefore H_D = P\int_0^x (\tan\rho - \tan\theta)dx$$

$$= P \cdot R\Big[\tan\rho\,(\sin\alpha - \sin\theta)$$

$$- (\cos\theta - \cos\alpha)\Big] \quad \ldots\ldots\ldots\ldots (5)$$

$$H_E = P\int_0^x (\tan\rho + \tan\theta)dx$$

$$= P\int_0^x \tan\rho\, dx + P\int_0^x \tan\theta\, dx$$

Since $x = R\sin\theta$

then $dx = R\cos\theta\, d\theta$

$$P\int_0^x \tan\rho\, dx = P \cdot R\int_0^\theta \tan\rho\cos\theta\, d\theta$$

$$= P \cdot R\tan\rho\sin\theta$$

$$P\int_0^x \tan\theta\, dx = P \cdot R\int_0^\theta \sin\theta\, d\theta$$

$$= P \cdot R(1 - \cos\theta)$$

$$\therefore H_E = P\int_0^x (\tan\rho + \tan\theta)dx$$

$$= P \cdot R\Big[\tan\rho\sin\theta + (1 - \cos\theta)\Big] \ldots (6)$$

In order to express Equations (5) and (6) in terms of unit stress at any value of θ, the horizontal forces H_D and H_E must be divided by the corresponding stock height, h_θ, Figure 4.

Since $h_\theta = h_1 - 2R(\cos\theta - \cos\alpha)$

$$\frac{H_D}{h_\theta} = S_{3D\theta} = \frac{P \cdot R\Big[\mu(\sin\alpha - \sin\theta) - (\cos\theta - \cos\alpha)\Big]}{h_1 - 2R(\cos\theta - \cos\alpha)} \quad \ldots (7)$$

$$\text{and } \frac{H_E}{h_\theta} = S_{3E\theta} = \frac{P \cdot R\Big[\mu\sin\theta + (1 - \cos\theta)\Big]}{h_1 - 2R(\cos\theta - \cos\alpha)} \quad \ldots\ldots (8)$$

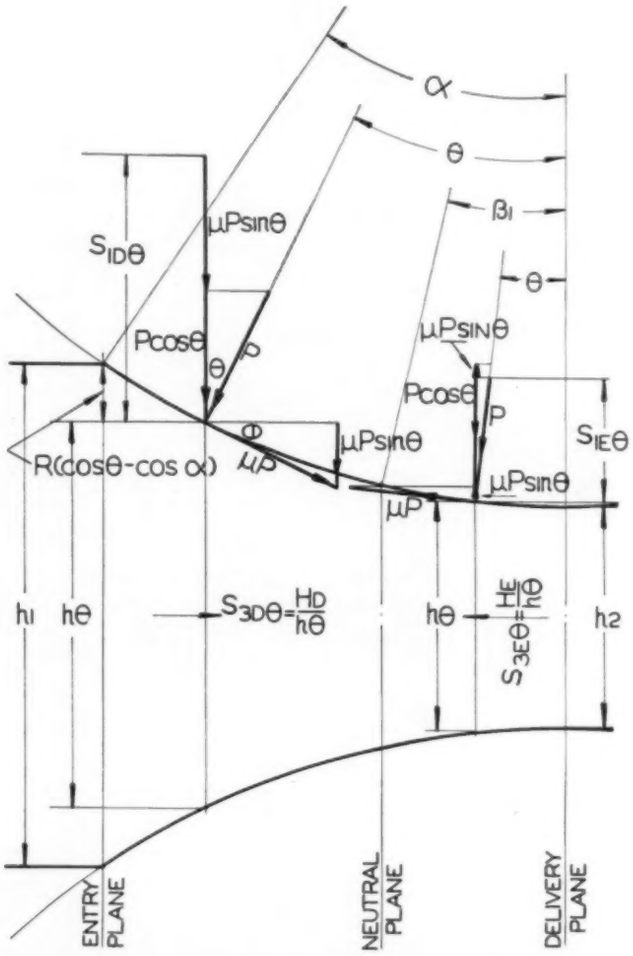


Figure 4 — Resolution of stresses acting on elemental cross sections within the arc of roll contact in accordance with the shear stress theory for the purpose of determining vertical and horizontal stresses without cumulative effects.

The equations for the determination of the ratio of the radial pressure to the compressive strength, $\frac{P}{S}$, and vertical pressure to compressive strength, $\frac{P_V}{S}$, may be determined by the utilization of the shear stress theory. For the condition between the entry and the neutral planes, Figure 4,

$S_{1D\vartheta} = P(\cos\theta + \mu\sin\theta)$

$$S_{3D\theta}=\frac{H_D}{h_\theta}=\frac{P\cdot R\left[\mu(\sin\alpha-\sin\theta)-(\cos\theta-\cos\alpha)\right]}{h_1-2R(\cos\theta-\cos\alpha)}$$

$S=S_{1D\theta}-S_{3D\theta}=$ Shear stress theory – Equation (1d)

$$S=P(\cos\theta+\mu\sin\theta)-\frac{P\cdot R\left[\mu(\sin\alpha-\sin\theta)-(\cos\theta-\cos\alpha)\right]}{h_1-2R(\cos\theta-\cos\alpha)}$$

$$\frac{P}{S}=\frac{1}{(\cos\theta+\mu\sin\theta)-\dfrac{R\left[\mu(\sin\alpha-\sin\theta)-(\cos\theta-\cos\alpha)\right]}{h_1-2R(\cos\theta-\cos\alpha)}}\quad\ldots\ldots(9)$$

$$\frac{P_V}{S}=\frac{S_{1D\theta}}{S}=\frac{(\cos\theta+\mu\sin\theta)}{(\cos\theta+\mu\sin\theta)-\dfrac{R\left[\mu(\sin\alpha-\sin\theta)-(\cos\theta-\cos\alpha)\right]}{h_1-2R(\cos\theta-\cos\alpha)}}\quad..(10)$$

For the condition between the neutral and the delivery planes, Figure 4,

$$S_{1E\theta}=P(\cos\theta-\mu\sin\theta)$$

$$S_{3E\theta}=\frac{H_E}{h_\theta}=\frac{P\cdot R\left[\mu\sin\theta+(1-\cos\theta)\right]}{h_1-2R(\cos\theta-\cos\alpha)}$$

$S=S_{1E\theta}-S_{3E\theta}=$ Shear stress theory – Equation (1d)

$$S=P(\cos\theta-\mu\sin\theta)-\frac{P\cdot R\left[\mu\sin\theta+(1-\cos\theta)\right]}{h_1-2R(\cos\theta-\cos\alpha)}$$

$$\frac{P}{S}=\frac{1}{(\cos\theta-\mu\sin\theta)-\dfrac{R\left[\mu\sin\theta+(1-\cos\theta)\right]}{h_1-2R(\cos\theta-\cos\alpha)}}\quad..(11)$$

$$\frac{P_V}{S}=\frac{S_{1E\theta}}{S}=\frac{(\cos\theta-\mu\sin\theta)}{(\cos\theta-\mu\sin\theta)-\dfrac{R\left[\mu\sin\theta+(1-\cos\theta)\right]}{h_1-2R(\cos\theta-\cos\alpha)}}\quad..(12)$$

All base curves illustrated in connection with this work, showing radial pressures for various points within the arc of roll contact, are plotted from solutions of Equations (9) and (11) for any given set of conditions. Correspondingly, all base curves showing vertical pressures are plotted from solutions of Equations (10) and (12).

APPLICATION OF PRANDTL[6] EQUATIONS

The horizontal force H_D acting on any vertical plane between the entry and the neutral points may be expressed by Equation (5). The location of this plane may be designated by the angle β_3 between the line of roll centers and the radius to the intersection of the plane with the roll arc. A corresponding vertical plane may be located between the neutral and the delivery points, which has an equal but opposing horizontal force H_E acting on it, expressed by Equation (6). The location of the latter plane may be designated by the angle β_4 between the line of roll centers and the radius to the intersection of the plane with the roll arc. The angle span between the bounding planes of equal and opposite horizontal forces may be designated as the $(\beta_3-\beta_4)$ angle. An angle of any magnitude may be arbitrarily chosen, and its distribution in terms of β_3 and β_4 may be determined so that the horizontal force H_D, acting in the delivery direction through the vertical plane at angle β_3, is equal to the horizontal force H_E, acting in the entry direction through the vertical plane at angle β_4. For illustration, if an arbitrary angle span of $\mu\cdot\alpha$ is chosen, i.e., $\beta_3-\beta_4=\mu\cdot\alpha$, then:

$$H_D=H_E$$

and substituting β_3 and β_4 for θ in Equations (5) and (6), respectively, we obtain:

$$P\cdot R\left[\mu(\sin\alpha-\sin\beta_3)-(\cos\beta_3-\cos\alpha)\right]=P\cdot R\left[\mu\sin\beta_4+(1-\cos\beta_4)\right]$$

Or $\mu\sin\beta_4=C-\mu\sin\beta_3-\cos\beta_3+\cos\beta_4\ldots.(13a)$

Where $C=\mu\sin\alpha+\cos\alpha-1$

Using $\mu=0.4$, $\alpha=10.065$ degrees, and $\mu\cdot\alpha=4.026$ degrees, and applying the relation $\beta_3=\beta_4+4.026$ degrees, Equation (13a) becomes, upon substitution:

$$0.4\sin\beta_4=0.054519-0.4\sin(\beta_4+4.026\text{ degrees})-\cos(\beta_4+4.026\text{ degrees})+\cos\beta_4\ldots(13b)$$

Using

$\sin(x+y)=\sin x\cos y+\cos x\sin y$

$\cos(x+y)=\cos x\cos y-\sin x\sin y$

and substituting values of applicable angles, Equation (13b) reduces to the form:

$(0.728799)\sin\beta_4=0.054519-(0.025614)\cos\beta_4\ldots(13c)$

Using

$$\cos\beta_4=\sqrt{1-\sin^2\beta_4}$$

Equation (13c) can be solved in terms of $\sin\beta_4$ as follows:

$$0.728799\sin\beta_4=0.054519-0.025614\sqrt{1-\sin^2\beta_4}$$

$$810.5823\sin^2\beta_4-121.1251\sin\beta_4+3.5305=0$$

Solving for sin β_4 by using the quadratic formula:

$$\sin \beta_4 = \frac{-(-121.1251) \pm \sqrt{(-121.1251)^2 - 4(810.5823)(3.5305)}}{2(810.5823)}$$

$$= \frac{121.1251 \pm 56.7821}{1621.1646}$$

There are two real and unequal roots:

Using negative sign:

$$\sin \beta_4 = \frac{64.3430}{1621.1646} = 0.03969$$

$$\beta_4 = 2.275 \text{ degrees}$$

Using positive sign:

$$\text{The alternate root} = \frac{177.9072}{1621.1646} = 0.10974$$

$$\text{The angle} = 6.301 \text{ degrees}$$

Since $\beta_3 - \beta_4 = 4.026$ degrees,

Then $\beta_3 = \beta_4 + 4.026$ degrees

$= 2.275$ degrees $+ 4.026$ degrees

$= 6.301$ degrees

$\therefore$ The alternate root $= \beta_3$

It will be observed that the angles dealt within the solution of Equation (13c) are small and extreme accuracy is required to arrive at mathematical solutions. When a solution is made in the terms of one alternate, a check on the accuracy of the solution can be obtained by solving in terms of the second alternate.

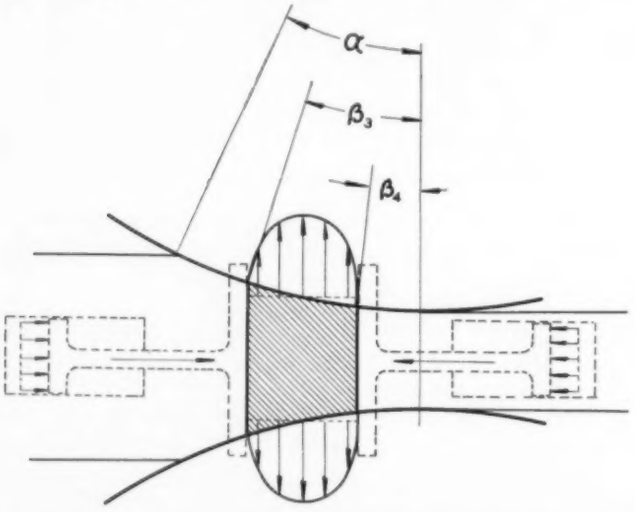


Figure 5 — Diagrammatic representation of the reactive vertical pressures resulting from equal and opposing cumulative horizontal forces acting on vertical planes through predetermined angles β_3 and β_4.

Up to this point the cumulative effects of horizontal pressures on normal pressures have not been considered. The stock in the roll arc between vertical planes through β_3 and β_4 is subjected to the horizontal pressures cumulated at those planes. The condition is diagrammatically represented by Figure 5, in which the planes through β_3 and β_4 are represented as platens actuated by hydraulic pistons. The total pressures on the pistons are opposite and equivalent to the cumulated horizontal pressures on the planes through β_3 and β_4. It can be noted that it is immaterial insofar as the effect of the platens is concerned, whether the pistons are flat, convex, or concave. It is also immaterial as to how the unit pressure is distributed on the pistons, whether it is uniform or non-uniform. The effect of the platens is determined only by the product of the projected area of the pistons and the total pressure exerted on them. Since the

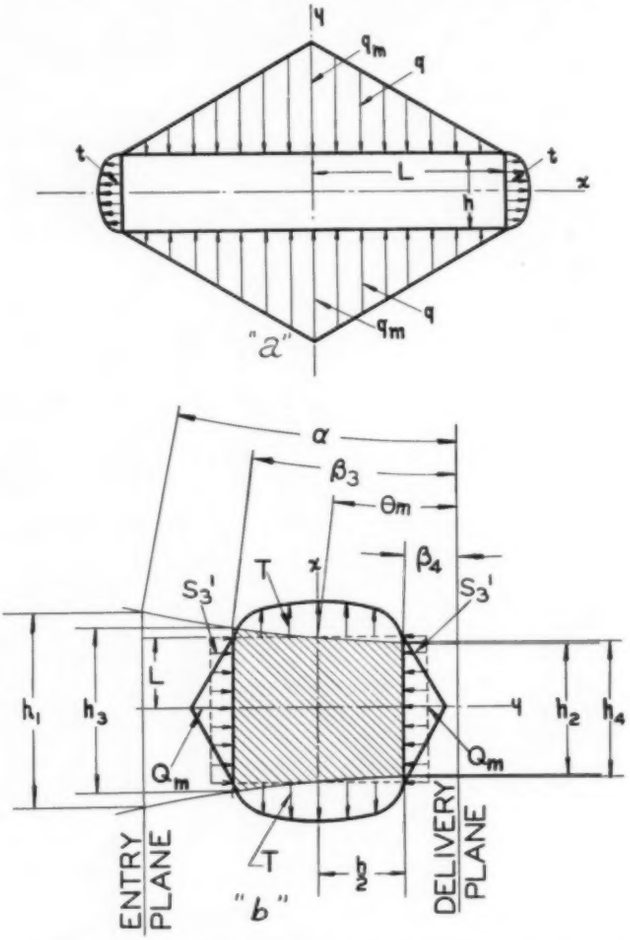


Figure 6 — Top "a" shows basic condition of the Prandtl equation — compression of a plastic material which adheres to the parallel compressing platens. On bottom "b" is seen application of the Prandtl equation to the condition of cumulative horizontal pressures in the roll arc by a 90-degree rotation of the axis of reference.

platens and the material between the platens "stick" in the sense used by Prandtl, his equations are directly applicable for the determination of the distribution of the normal pressures between β_3 and β_4 that result from the cumulated horizontal pressures acting on the vertical planes through β_3 and β_4.

In connection with Orowan's theory of rolling, Underwood discusses Prandtl's investigation of stress distribution in the case of a plastic mass compressed between two parallel plates of such roughness as to cause adherence between the material and the plates. The following is quoted directly from Underwood, page 241:

"Then if q is the vertical and t the horizontal pressure, and τ the shear stress in vertical or horizontal

planes, h the distance between the plates, S the yield stress of the material in compression, Prandtl states that the stress distribution is given by the following equations:

$$q = C + \frac{S}{h}x$$

$$t = C + \frac{S}{h}x - S\sqrt{1 - 4y^2/h^2}$$

$$\tau = -\frac{S}{h}y$$

where C depends on the boundary conditions. If $q = O$ at the edge of the plate where $x = \pm L$, then $C = \pm \frac{S}{h}L$. The resulting stress distribution is then as shown in . . . "

Figure 6(a) of this paper corresponds to the one referred to in the previous sentence.

The modification which is required for the application of Prandtl's equations to the present work is simply a rotation of 90 degrees of the frame of reference of Figure 6(a) to the position shown in Figure 6(b) so that the parallel plates correspond to the vertical planes passing through β_3 and β_4, h corresponds to the horizontal distance between the vertical planes through β_3 and β_4, and L corresponds to the vertical distance from the horizontal center line of the stock to the roll arc as determined on a vertical center line between the vertical planes through β_3 and β_4. For quantitative applications of the equations, finite determinations of h and L, Figure 6(b), are necessary. Since β_3 and β_4 are determinable for any arbitrarily chosen angle span,

$$\therefore h = R(\sin\beta_3 - \sin\beta_4) \quad \ldots\ldots (14)$$

The determination of the quantity L is as follows:

$$2L = h_1 - 2R\left[(1 - \cos\alpha) - (1 - \cos\theta_m)\right]$$

$$= h_1 - 2R\left[\cos\theta_m - \cos\alpha\right]$$

where θ_m is the angle that locates the vertical center line between the planes through β_3 and β_4 on which the distance 2L is measured and h_1 is the initial stock height.

$$h = R(\sin\beta_3 - \sin\beta_4)$$

$$R\sin\theta_m = R\sin\beta_4 + \frac{h}{2}$$

$$\sin\theta_m = \sin\beta_4 + \frac{h}{2R}$$

$$= \sin\beta_4 + \frac{\sin\beta_3 - \sin\beta_4}{2}$$

$$= \frac{\sin\beta_3 + \sin\beta_4}{2}$$

It follows that:

$$\cos\theta_m = \sqrt{1 - \frac{(\sin\beta_3 + \sin\beta_4)^2}{4}}$$

$$\therefore 2L = h_1 - 2R\left[\sqrt{1 - \frac{(\sin\beta_3 + \sin\beta_4)^2}{4}} - \cos\alpha\right]$$

$$= R\left[\frac{h_1}{R} + 2\cos\alpha - 2\sqrt{1 - \frac{(\sin\beta_3 + \sin\beta_4)^2}{4}}\right]$$

$$L = R\left[\frac{h_1}{2R} + \cos\alpha - \sqrt{1 - \frac{(\sin\beta_3 + \sin\beta_4)^2}{4}}\right]$$

$$\ldots\ldots (15)$$

An approximation is introduced at this point in the quantitative application of Prandtl's equations by the utilization of the determined distance L in lieu of the actual stock heights, h_3 and h_4 — Figure 6(b) — and by the use of the average horizontal unit stress S_3' where:

$$S_3' = \frac{S_{3D} + S_{3E}}{2} \quad \ldots\ldots (16)$$

Taking into consideration the action of both rolls, the average horizontal unit pressure becomes:

$$2S_3' = S_{3D} + S_{3E}$$

From Prandtl's equation, Figure 6(a), and the statement of boundary conditions, the maximum value (q_m) of q is developed when $x = 0$, i.e.:

$$q_m = \frac{SL}{h} \quad \ldots\ldots (17)$$

The maximum equivalent pressure Q_m, as indicated in Figure 6(b) is:

$$Q_m = 2 \cdot 2S_3' = 4S_3'$$

and if T in Figure 6(b) is designated as the variable cumulative unit stress of the modified Prandtl equation corresponding to t in the original application, Figure 6(a), then:

$$\frac{Q_m}{q_m} = \frac{T}{t}$$

$$T = \frac{Q_m}{q_m} \cdot t = \frac{4S_3'}{q_m} \cdot t \quad \ldots\ldots (18)$$

where $q_m = \frac{SL}{h}$,

$$t = S\sqrt{1 - 4y^2/h^2}$$

and y = variable horizontal distance from the midpoint of h to either one of the two vertical planes at angles β_3 and β_4, at which determinations for the value of T are made.

Reference to Equations (7) and (8) shows that their solutions are expressed in terms of P, the radial unit roll pressure. When the values of T are plotted as ratios of the variable cumulative unit radial pressures to the compressive strength, then:

$$\frac{T_R}{S} = \frac{4S_3' \cdot h}{S \cdot L}\sqrt{1 - 4y^2/h^2} \quad \ldots\ldots (19)$$

Correspondingly, when the values of T are plotted as ratios of the vertical components of T_R to the compressive strength,

$$\frac{Ty}{S} = \frac{4S_3' \cos\left[\beta_3 - \beta_4\right]}{S \cdot L} \cdot h\sqrt{1 - 4y^2/h^2} \quad \ldots\ldots (20)$$

where $\cos\left[\beta_3 - \beta_4\right]$ implies that in the determination of S_3', S_{3D} and S_{3E} must be multiplied by $\cos \beta_3$ and $\cos \beta_4$ respectively.

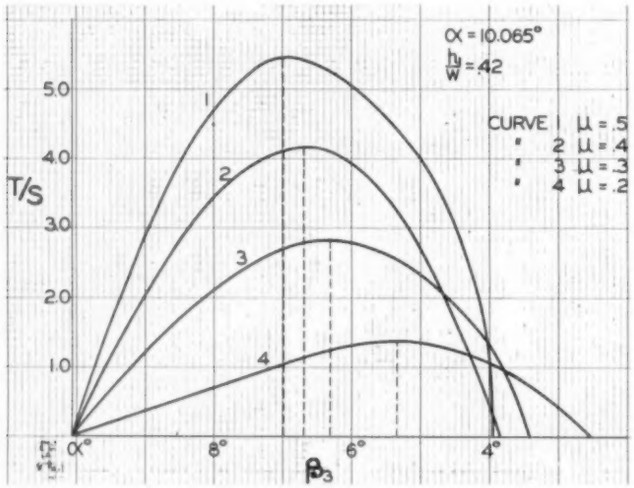


Figure 7 — Curves illustrate the determination of the angle span at which maximum values are derived from the modified Prandtl equations for given basic conditions.

For any given conditions of μ and $\frac{h_1}{W}$ ratio, the determined values for $\frac{T}{S}$ of Equations (19) and (20) where $y = 0$, will follow the curve patterns shown by Figure 7. From the foregoing equations $\frac{T}{S}$ may be plotted for any random series of angle spans $(\beta_3 - \beta_4)$ within the arc of roll contact. The determined values of $\frac{T}{S}$ may then be plotted against the corresponding angle β_3, Figure 7. The maximum value of $\frac{T}{S}$ and the corresponding maximum value of β_3 may be determined from the plotted curve.

CONSTRUCTION OF PRESSURE DIAGRAMS

Figure 8 illustrates the details of construction of pressure diagrams. In order to better illustrate the trends of the pressure curves with chosen variables, practical drafting conditions on the roughing mills of a 96-in. continuous plate mill were selected in lieu of the 44-in. slabbing mill drafting practices. The roughing mills consist of three 2-high stands of 52-in. diameter steel rolls and 96-in. body lengths. For Figure 8, a 42 per cent reduction from 1.90 to 1.10 in. was taken with μ assumed as 0.4.

The base curve ① was constructed from a solution of Equations (9) and (11) for varying values of θ. The base curve represents the unit pressures generated, expressed in terms of $\frac{P}{S}$, by reason of the frictional forces without the cumulative effect of such forces. A series of angle spans $(\beta_3 - \beta_4)$ were chosen within the

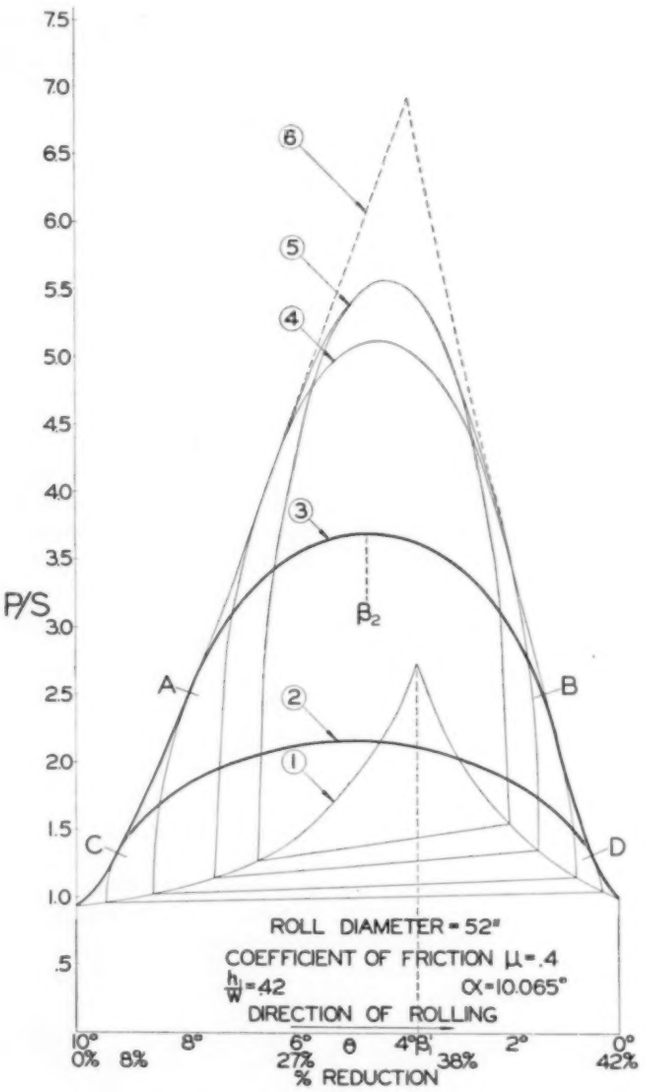


Figure 8 — Method of construction of the theoretical pressure diagrams is shown in this figure.

arc of roll contact, and their distributions were determined for the condition of equal horizontal pressures through the vertical planes at their extremities. The cumulative horizontal pressure effects between the various angle spans in terms of $\frac{P}{S}$ were determined by

solutions of the applicable Equation (19). The determined values were plotted from bases drawn through the intersections of the $\beta_3 - \beta_4$ planes with the base curve. The angle span ⑤ corresponding to the maximum modified Prandtl curve values was determined from a graphical solution corresponding to Figure 7. The normal pressure curve envelope was drawn tangent to the series of modified Prandtl curves. The dotted extension of the curve ⑥ represents the sharp peaked type of curve that would be derived from the application of current theories of rolling.

In connection with his theory of rolling, Orowan assumes for all conditions that the criterion for "sticking" used in the sense of the beginning of the angle of no relative motion between stock and rolls is expressed by $\mu P = \frac{S}{2}$, i.e., sticking begins at that normal pressure which when multiplied by the coefficient of friction is equivalent to the shear strength of the stock. It is believed that this criterion is applicable to a rolling condition of relatively free spread, since the volume of stock reduced from heights h_3 to h_4 in the angle of no slippage can move by spread at right angles to the direction of rolling. When, however, by reason of closed passes or dimensional ratios, spread is relatively restricted, the volume of stock reduced from h_3 to h_4 must move adjoining stock in compression toward either the entry or the delivery planes. It is believed, therefore, that under the latter condition, the criterion for sticking is expressed by $\mu P = S$.

The reduction of ingots to slabs on the 44-in. mill is a rolling condition of relatively free spread, while the reduction of wide slabs on the 96-in. roughing mills is a condition of relatively restricted spread. Though the application of both criteria is illustrated in Figure 8, it may be stated at this point that the trends developed for the end purpose of this work are identical with the use of either criterion.

For the application of the criteria to Figure 8:

1. $\mu P = \frac{S}{2} \quad \frac{P}{S} = \frac{1}{2\mu} = 1.25$

2. $\mu P = S \quad \frac{P}{S} = \frac{1}{\mu} = 2.50$

Curves ② and ③, Figure 8, are derived from Equation (19) by trial to be tangent at the two respective values of $\frac{P}{S}$. In the portion of the roll arc between A and B of Curve ③, frictional forces are not operative, as there is no relative motion in this portion of the arc between the stock and the rolls. A normal pressure represented by Curve ③ is effective in this portion of the roll arc, since it is the effect of the accumulated horizontal pressures acting on the planes at the related angles β_3 and β_4. Consequently, the curve in heavy outline, including a portion of Curve ③, is the normal pressure diagram when the criterion is $\mu P = S$. Correspondingly, the curve in heavy outline, including a portion of Curve ②, is the normal pressure diagram when the criterion is $\mu P = \frac{S}{2}$.

Equation (4), based on the construction shown in Figure 3, has been accepted as the correct mathematical derivation of the magnitude of the neutral angle, β_1. The construction of Figure 9 is based on the relative magnitude of the net horizontal forces within the arc of roll contact. When the horizontal forces are expressed in terms of ratios of unit stresses, $\frac{P}{S}$, Equations (9) and (11) and plotted, it is evident that Equation (4) expresses only a close approximation of

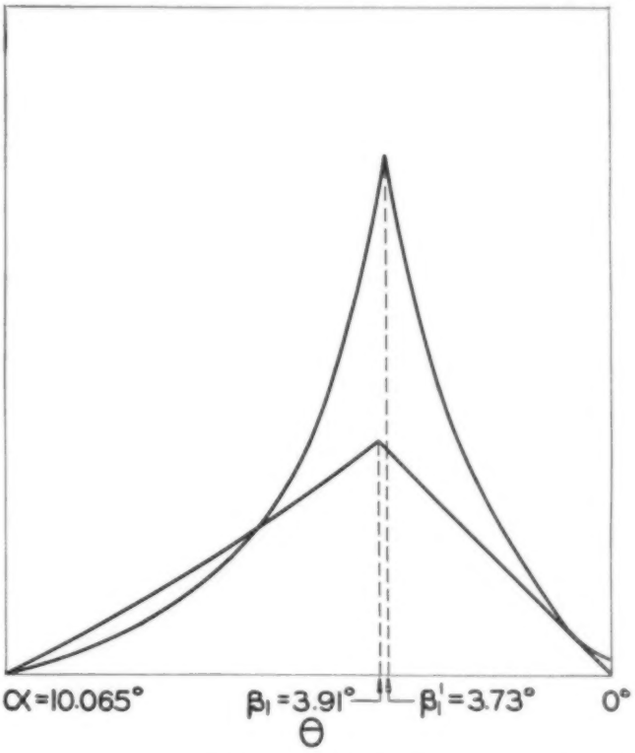


Figure 9 — Comparison of magnitude of the apparent neutral angle β_1 derived from Siebel's construction with corresponding angle derived from base curve of unit stress. Basic conditions are those of Figure 8.

the magnitude of β_1. Further, if the neutral angle is designated as the angle between the line of roll centers and the radius to the point on the roll arc coincident with the peak of the $\frac{P}{S}$ diagram, β_2 of Figure 8, then the discrepancy between the apparent and the actual angles increases. Accordingly, in this work β_1 is designated as the apparent neutral angle and β_2 as the actual.

In a prior paper [7]; the author treated the stock height to equivalent die-width ratio, $\frac{h_1}{W}$, qualitatively. In the current work the ratio is treated quantitatively. For Figure 10 a constant contact angle is assumed; initial stock heights of 4.55, 3.64, 2.73, 2.27, and 1.90 in. correspond to the percentage reductions and $\frac{h_1}{W}$ ratios

indicated for Curves ① to ⑤, respectively. No sticking within the arc of contact is assumed. The pressure diagrams are constructed on the basis of the modified Prandtl curves of maximum magnitudes that can be derived from the stated conditions as illustrated by Curve ⑤ of Figure 8. The trend of the pressure diagrams with decreasing $\frac{h_1}{W}$ ratios is similar to what would be anticipated with the application of current theories, with the exception of the fact that the curve peaks are rounded instead of being sharp.

For the rolling conditions represented by the pressure diagrams of Figure 11, the rolling of wide slabs is assumed for which the dimensional ratios constitute a practical restriction for spread. In other respects the

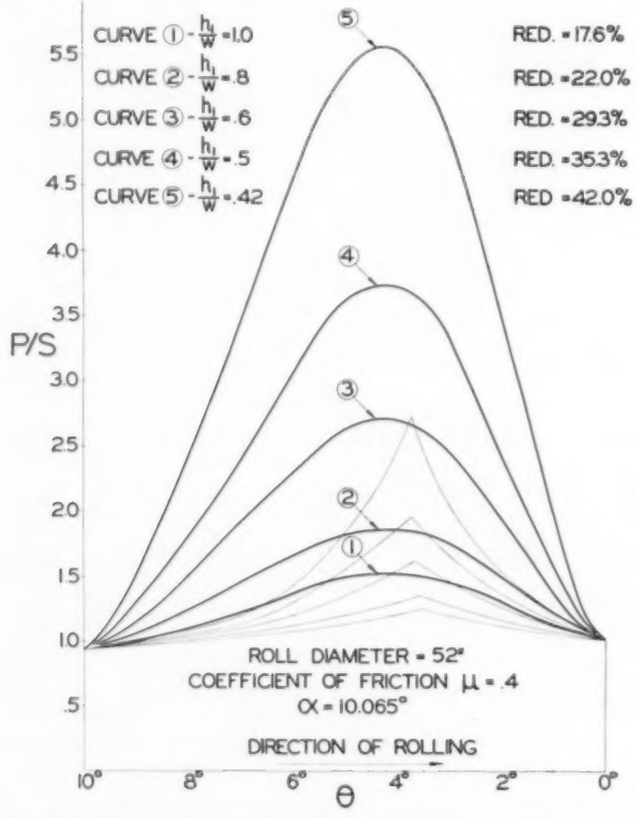

CURVE ① - h1/W = 1.0 RED. = 17.6%
CURVE ② - h1/W = .8 RED. = 22.0%
CURVE ③ - h1/W = .6 RED. = 29.3%
CURVE ④ - h1/W = .5 RED. = 35.3%
CURVE ⑤ - h1/W = .42 RED. = 42.0%
P/S
ROLL DIAMETER = 52"
COEFFICIENT OF FRICTION μ = .4
α = 10.065°
DIRECTION OF ROLLING
θ

Figure 10 — Pressure diagrams for variable h_1/W ratios when the maximum values derived from the Prandtl equations are used as criteria.

basic conditions assumed are identical with those assumed for Figure 10. By reason of the restriction for spread, the criterion for sticking is assumed as $\mu P = S$. In comparing the pressure diagrams of Figure 11 with those of Figure 10, it will be noted that Curves ①, ②, and ③ are unaffected but that the peaks of Curves ④ and ⑤ are appreciably depressed and broadened.

Referring to Figure 12, the rolling conditions therein represented assume the rolling of narrow slabs for which the dimensional ratios permit an appreciable spread. As before, other conditions assumed are identical to those of Figure 10. Under these conditions, the criterion assumed for sticking is $\mu P = \frac{S}{2}$. A comparison of the pres-

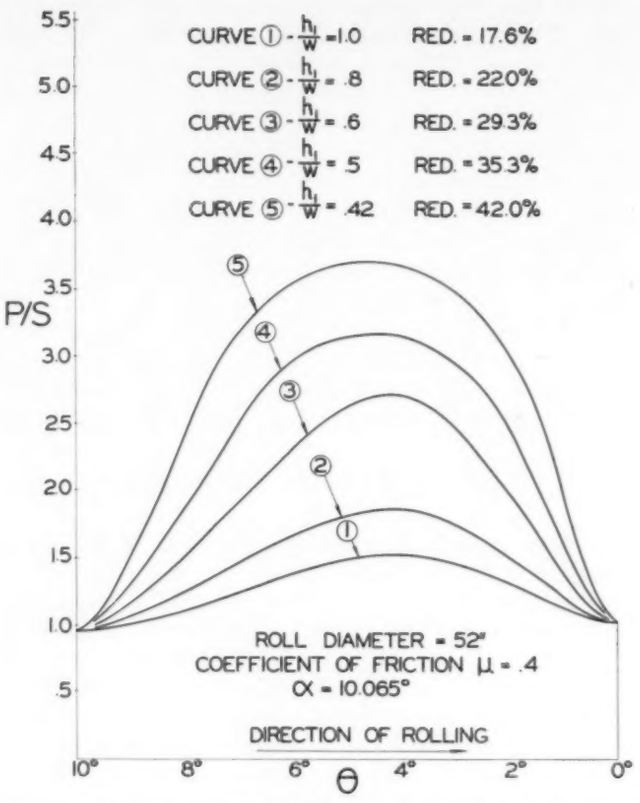
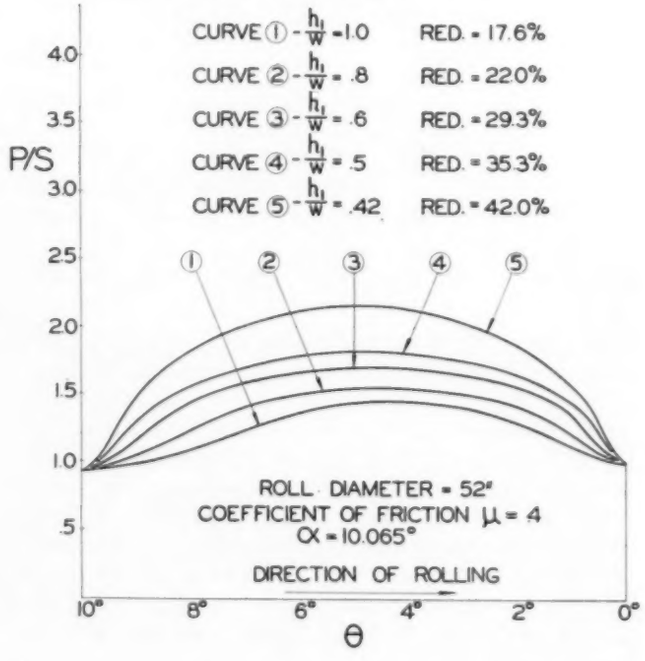

CURVE ① - h1/W = 1.0 RED. = 17.6%
CURVE ② - h1/W = .8 RED. = 22.0%
CURVE ③ - h1/W = .6 RED. = 29.3%
CURVE ④ - h1/W = .5 RED. = 35.3%
CURVE ⑤ - h1/W = .42 RED. = 42.0%
P/S
ROLL DIAMETER = 52"
COEFFICIENT OF FRICTION μ = .4
α = 10.065°
DIRECTION OF ROLLING
θ

Figure 11 — Pressure diagrams for variable h_1/W ratios when the criterion for sticking is $\mu P = S$.

sure diagrams of Figures 12 and 10 shows all curve peaks appreciably depressed and broadened. These illustrations may serve to explain why in the past, under like drafts, total rolling loads could not be correlated in simple ratios with stock width dimensions.

For Figure 13 the rolling of wide plates with no sticking is assumed. The initial stock height is 1.9 in., the reduction is 42.0 per cent, the contact angle is

Figure 12 — Pressure diagrams for variable h_1/W ratios when the criterion for sticking is $\mu P = S/2$.


CURVE ① - h1/W = 1.0 RED. = 17.6%
CURVE ② - h1/W = .8 RED. = 22.0%
CURVE ③ - h1/W = .6 RED. = 29.3%
CURVE ④ - h1/W = .5 RED. = 35.3%
CURVE ⑤ - h1/W = .42 RED. = 42.0%
P/S
ROLL DIAMETER = 52"
COEFFICIENT OF FRICTION μ = .4
α = 10.065°
DIRECTION OF ROLLING
θ

constant at 10.065 degrees, and the coefficient of friction μ is varied in 0.1 increments from 0.2 to 0.5, inclusive. The curves are developed for the maximum values that can be derived from the modified Prandtl equations. The increase of peak values with increasing coefficients of friction follows the trend that would be anticipated from current theories.

Conditions identical to the foregoing were assumed for Figure 14 with the added assumption that sticking at the $\mu P = S$ criterion occurs. The peaks of the pressure diagrams increase up to $\mu = 0.3$ and decrease with the

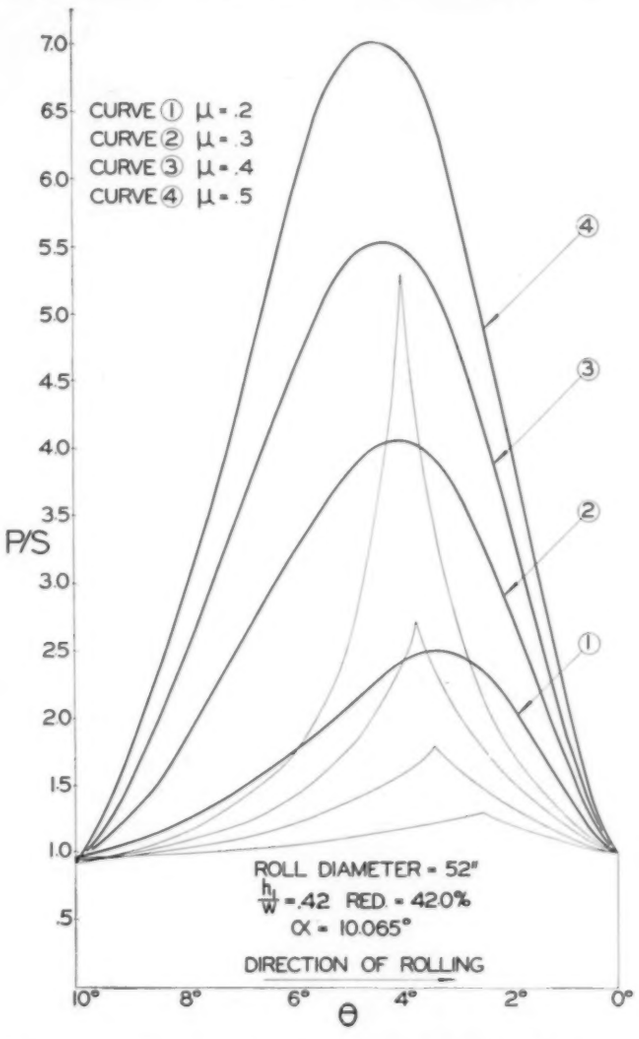


Figure 13 — Pressure diagrams for variable coefficients of friction when the maximum values derived from the Prandtl equations are used as criteria.

higher coefficients of friction. This development is inconsistent with the results attained from current theories of rolling which will show continually increasing pressure peaks with increasing coefficients of friction. Polakowski[8], however, also found by compression experiments on cold steel cylinders, that within a considerable range, pressures decreased with higher coefficients of friction. The following is a quotation from Polakowski's conclusions:

"Experimental evidence is given which shows that, for a wide range of initial conditions, the increase of end-surface friction during compression causes a decrease of the resistance to deformation, thus contradicting the generally accepted view that the resistance to compression under frictionless conditions is the least possible."

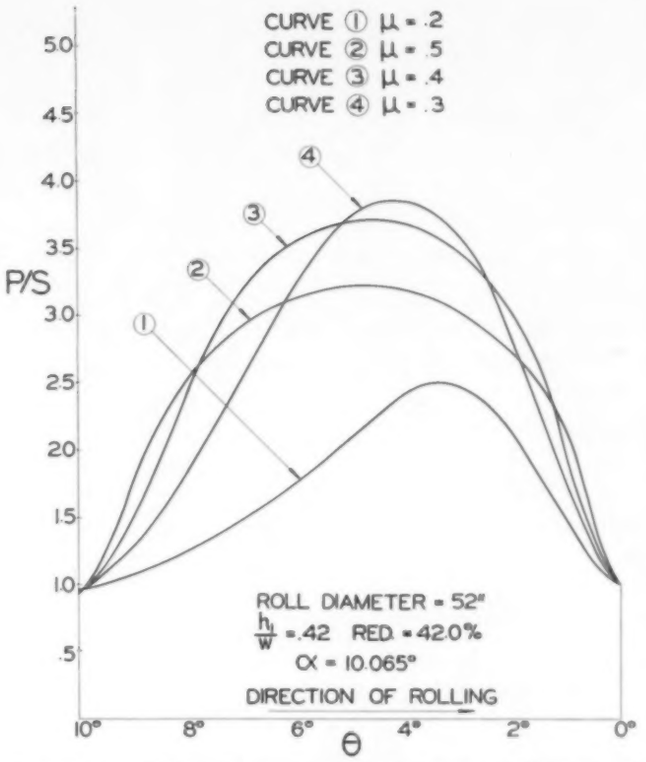
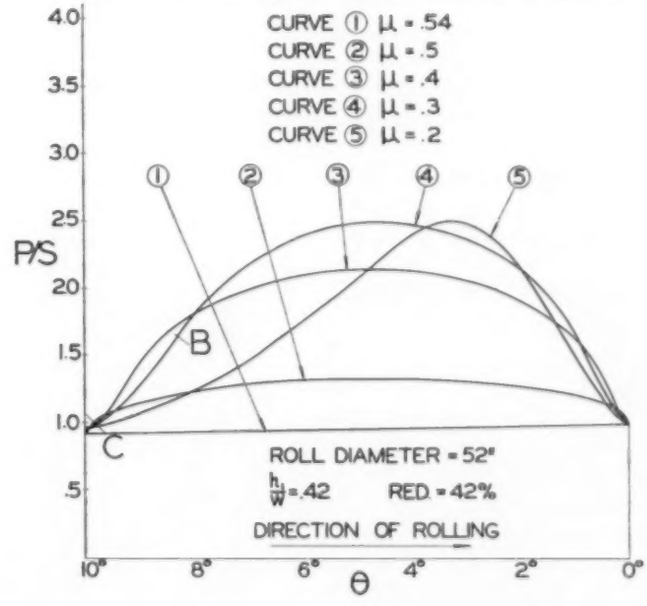


Figure 14 — Pressure diagrams for variable coefficients of friction when the criterion for sticking is $\mu P = S$.

For Figure 15 the rolling of narrow slabs was assumed, permitting unrestricted spread to occur. All other conditions are identical with those of the prior case. Similar to the prior case, the pressure diagrams increase up to $\mu = 0.3$ and decrease with higher values. Since the criterion for sticking is:

$$\mu P = \frac{S}{2},$$

Figure 15 — Pressure diagrams for variable coefficients of friction when the criterion for sticking is $\mu P = S/2$.



or $$\frac{P}{S}=\frac{1}{2\mu} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (21)$$

as μ approaches a value of 0.54, a condition of sticking over the entire arc of contact is approached. This may be verified mathematically from the following analysis:

Equation (1d) was given as:

$$S = S_{3D\theta} - S_{3D\theta} = \text{Shear stress theory}$$

Since for a condition of sticking over the entire arc of contact, $S_{3D\theta}=0$, then modifying Equation (9) for this condition:

$$\frac{P}{S}=\frac{1}{\cos\theta+\mu\sin\theta}=\frac{1}{\cos\alpha+\mu\sin\alpha} \quad \ldots\ldots\ldots\ldots (22)$$

Combining Equations (21) and (22), rearranging terms and simplifying, we obtain:

$$\mu_s=\frac{\cos\alpha}{2-\sin\alpha} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)$$

where μ_s is the coefficient of friction which results in sticking over the entire roll arc.

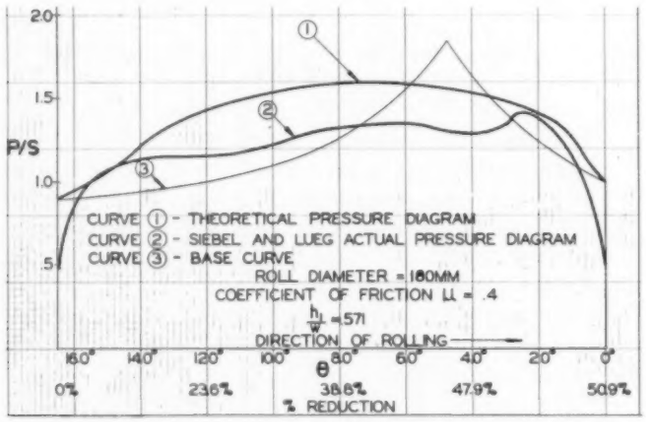


Figure 16 — Theoretical pressure diagram is compared with an actual pressure diagram from a hot rolling test by Siebel and Lueg. Spread is 22 mm to 29.3 mm or 33.2 per cent. Criterion $\mu P = S/2$; $S = 20$ kg/mm². Reference — Underwood Figure 95.

Considering practical rolling ranges where the arc of contact may vary from 0 to 30 degrees, the value of μ_s which will result in sticking over the entire arc will vary from a minimum value of 0.5 to a maximum value of 0.577. For the condition of Figure 15 where $\alpha = 10.065$ degrees, $\mu_s = 0.54$. The significance of this derivation in relation to Figure 15 is that as μ approaches 0.54 the pressure diagram approaches the sloping line between the entry and the delivery planes shown as Curve ①.

Figure 16 is a comparison of a pressure diagram derived from an application of the present work with the actual measured pressures obtained by Siebel and Lueg(9) in a hot rolling test. The latter diagram is shown as Figure 95 by Underwood. The rolling conditions as stated were used for the development of the theoretical pressure diagram. Figure 17 is a corresponding comparison of a theoretical diagram and the actual Siebel and Lueg pressure measurements obtained in a cold rolling test. The latter is designated as Figure 90(a) by Underwood; and as in the hot rolling test, the rolling conditions stated were used in the development of the theoretical pressure diagram. No corrections were introduced in either case to improve the coincidence of theoretical and actual diagrams.

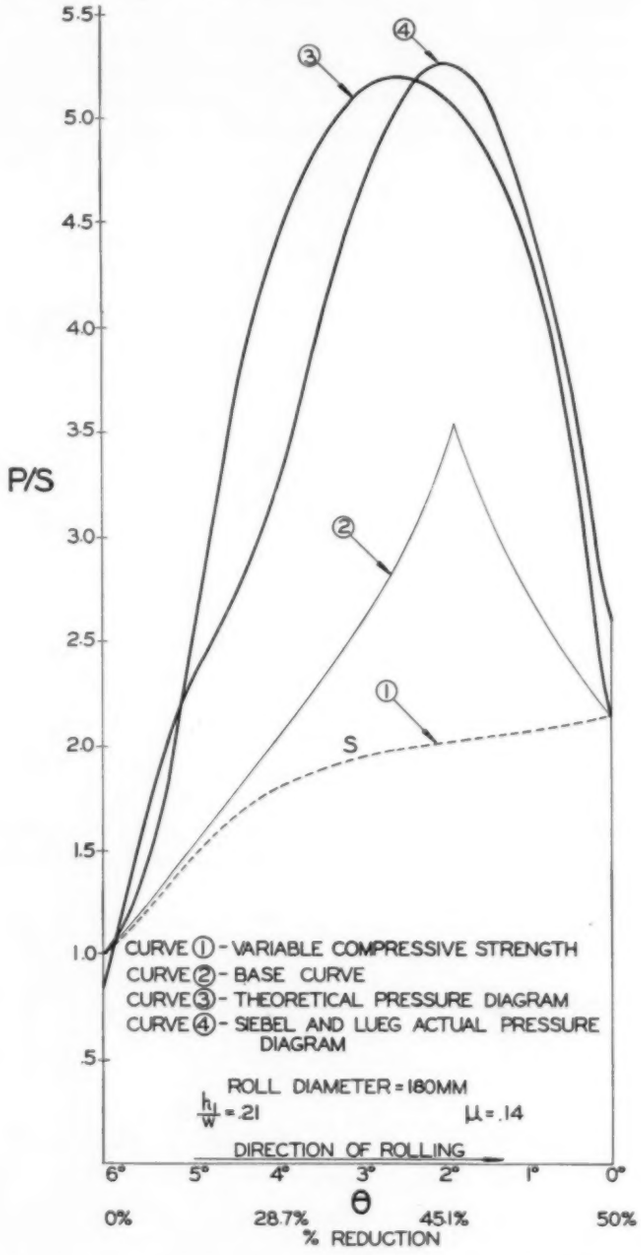


Figure 17 — Theoretical pressure diagram compared with an actual pressure diagram from a cold rolling test by Siebel and Lueg. Spread is 30 mm to 30.8 mm or 2.7 per cent. Criterion $\mu P = S$. Reference: Underwood Figure 90 (a).

APPLICATION TO SLAB ROLLING

In the course of a study of rolling practices at the 44-in. slabbing mill at South works, numerous detailed observations were made. These observations included drafting practices, roll contact times, time increments between passes, total rolling times and temperature drops from initial to final passes. From this infor-

mation, the approximate average temperature drop in the arc of roll contact was determined. The following is typical of the basic data and method of determination:

Ingot size	= 29 × 54-in. hot topped
Product size	= 5½ × 50 in.
Average draft	= 1.0 in.
Average number of passes	= 23
Average rolling time	= 2.58 minutes
Average roll contact time	= 1.47 minutes
Average rpm	= 45
Average temperature loss	= 365 F
Roll diameter (D)	= 42.5 in.
From above, average length of arc of roll contact	= 4.62 in.

Average time increment required for stock to pass through the arc of roll contact is:

$$\frac{60}{45} \times \frac{4.62}{42.5 \times \pi} = 0.046 \text{ seconds}$$

On the assumption that the temperature drop is approximately equivalent in roll contact and interval time, the temperature drop in the arc of roll contact is determined as follows:

$$\frac{365 \times 0.046}{2.58 \times 60} = 0.108 \text{ F}$$

Based on the foregoing and similar calculations it was concluded that for hot flat rolling of this type, the effect of temperature drop in the arc of roll contact was negligible on the compressive strength S. No attempt was made, therefore, to include a variation of S due to temperature drop in the arc of roll contact in the construction of the normal pressure curves.

In order to determine the approximate range of coefficients of friction for the unit previously referred to, tests were made on inclined planes corresponding in composition and surface to rolls used in the unit. Since knurled rolls have been used for several years and vary in surface conditions in the course of a campaign from newly knurled to a condition approaching knurling obliteration, the sliding surfaces correspondingly ranged from new knurling to an average rolled surface without knurling. The test pieces, heated to rolling temperatures with protection to minimize scale formation, likewise, ranged from those rolled on newly knurled rolls to those rolled on plain rolls. Efforts were made to remove the scale that did form in the heating process incident to the conduct of the tests. The following average determinations were made for 0.08 C, 0.48 Mn test pieces:

$\mu = 0.61$ = Static μ for knurled rolls and knurled test piece.

$\mu = 0.55$ = Sliding μ for knurled rolls and knurled test piece.

$\mu = 0.37$ = Static μ for plain rolls and plain test piece.

$\mu = 0.31$ = Sliding μ for plain rolls and plain test piece.

It was recognized that the assumption of a uniform value of μ through the arc of roll contact might introduce a degree of error in the calculations by reason of a variation in the value of μ with the variation of the relative velocities of stock and rolls. Consideration was given to the approximate degree of error which might be introduced under the condition of the maximum velocity differential in the rolling of the 29 × 54-in. ingot to the 5½ × 50-in. slab size in the last pass at 60 rpm.:

Initial stock height h_1 = 6.5 in.

Delivered stock height h_2 = 5.5 in.

Per cent reduction = 15.4 per cent

The maximum forward slip from the equation $\frac{f^2}{32}\left(\frac{D}{h_2} - 1\right)$ where f is the friction angle expressed in radians, is equal to 5.2 per cent.

The peripheral velocity of the rolls at 60 rpm is 11.1 fps. The delivery velocity of the stock, considering forward slip, = 11.7 fps. Neglecting spread, then from the constancy of volume principle, the entry velocity of the stock is:

$$V_1 = \frac{V_2 h_2}{h_1} = 9.9 \text{ fps}$$

The differential velocity between stock and rolls ranges from a maximum of 2.2 fps at the entry plane to 0 in the arc of no relative motion. Tafel[10], [11] conducted hot rolled tests to determine the variation of μ with velocity. Reference to his graph representing results with rough rolls, shows practically no difference in the value of μ in the range of 0 to 2.2 fps velocities. On this basis it was concluded that no error was introduced by considering the value of μ uniform through the arc of contact in this work.

In the initial stages of the breakdown of ingots to slabs in the size ranges considered, the flow of metal in roll contact is somewhat greater than in the central portions of the ingot. This is indicated by concave contours of both sides and ends. In the later breakdown stages, the flow of metal in interior portions is greater than in the roll contact surfaces as evidenced by the convex contours of both sides and ends. Under either condition, when the total differential is considered distributed over the entire length of product, the deviation from rectilinear deformation is slight. In an appreciable range in both directions, when $\frac{h_1}{W} = 2$, the deformation is rectilinear. This has been confirmed by tests by the author, as well as by prior tests by Ekelund[12] and others.

Because of the foregoing, it is concluded that the original assumptions made in connection with the construction of the base curves are for all practical purposes, applicable in fact to the rolling of ingots into slabs. It is further concluded that for all practical purposes, the analysis represented by this work is applicable to this rolling condition. Since the rolling condition is one of relatively free spread, pressure diagrams with the criterion of $\mu P = \frac{S}{2}$ are applicable.

Reference to the pressure diagrams shows that the rolling pressures are appreciably less for the condition of $\mu = 0.50$ than for the condition of $\mu = 0.30$. Surface tears, however, generally have the typical physical characteristics of tensile breaks, indicative of tensile rather than compressive stresses being the source. It is necessary, therefore, to carry the analysis one step further.

Frictional forces are effective only in the portion of

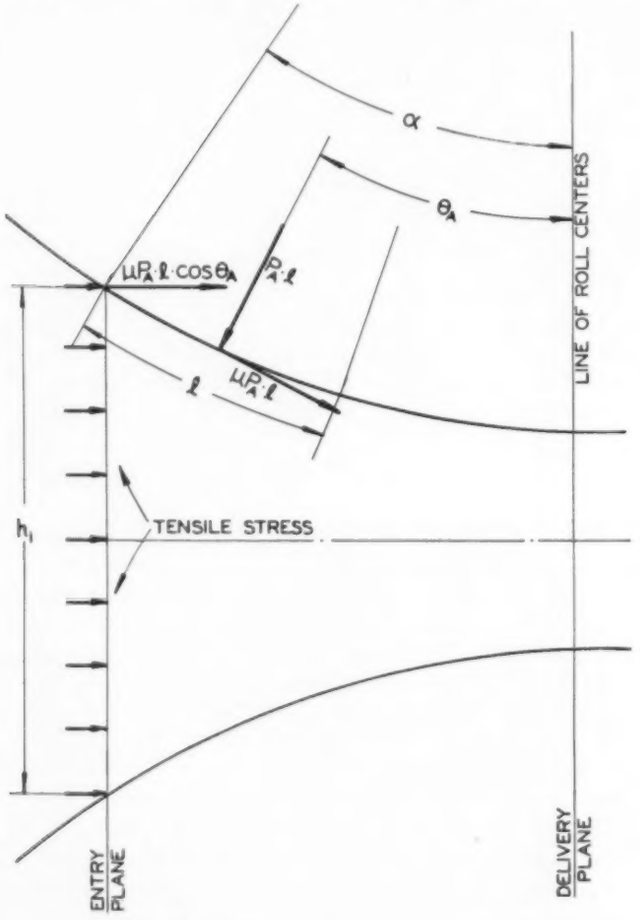


Figure 18 — Illustration shows derivation of approximate maximum tensile stress for material in the process of rolling.

the roll arc where there is relative motion between the rolls and the stock. Referring to the entry side of the pressure diagrams of Figure 15, such relative motion takes place only between the entry plane and the beginning of the angle of no motion indicated as Points C and B on the two respective curves. Considering the action of both rolls on the stock, the approximate tensile stress acting on the stock at the entry plane is — Figure 18:

$$\text{Tensile stress} = \frac{2\mu \, P_A \cos \theta_A \, l}{h_1} \quad \ldots\ldots\ldots (24)$$

Where P_A = Average radial roll pressure over l on entry side of neutral plane.

θ_A = Angle between line of roll centers and radius to midpoint of l.

l = Length of arc of slippage (α to B or C).

Considering the two specific curves referred to, for:

$\mu = 0.3$, Tensile stress = 0.335 S

$\mu = 0.5$, Tensile stress = 0.037 S

The tensile stresses include those due only to the frictional forces generated by the rolls and do not include tensile stresses due to compression similar to those generated in adjoining surfaces by an open hot shear cut on billets.

When plain rolls are knurled to alter the coefficient of friction from approximately 0.31 to 0.55, the analysis shows that the results which were actually achieved can be anticipated; namely:

1. Reduction in surface tearing tendency.
2. Reduction in roll breakage.
3. Reduction in roll wear.
4. Reduction in power consumption.

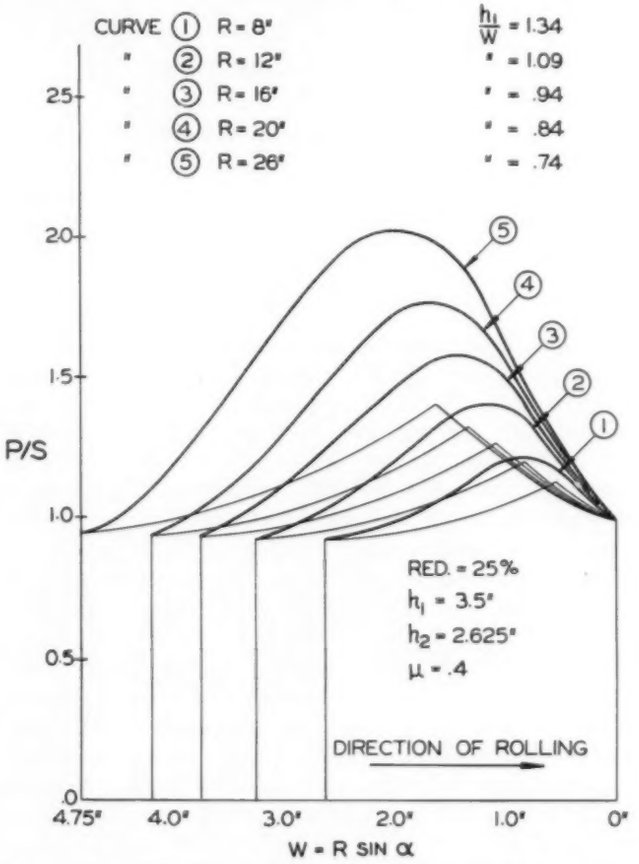


Figure 19 — Pressure diagrams for variable roll diameters when the criterion for sticking is $\mu P = S$.

EFFECT OF ROLL DIAMETERS

The following conditions are assumed for Figure 19:

Roll diameters = 52, 40, 30, 24, and 16 in.
Initial stock height h_1 = 3.5 in.
Delivered stock height h_2 = 2.625 in.
Coefficient of friction, μ = 0.4
Sticking criterion, μP = S

Contact angles of 10.53, 12.00, 13.43, 15.52, and 19.04 degrees are coincident with the incremental decrease of roll diameters from 52 to 16 in. Pressure

diagrams for the stated conditions shown as Curves ① to ⑤, inclusive, are constructed from solutions of applicable equations and graphical determinations as illustrated by Figure 8. The pressure diagrams indicate that for the conditions stated, roll pressures increase with increased roll diameters.

The conditions assumed for Figure 20 are identical with those assumed for Figure 19 with the exception that relatively free in lieu of restricted spread is assumed, with the sticking criterion being $\mu P = \frac{S}{2}$.

Corresponding with Figure 19, Curves ① to ⑤, inclusive, represent the pressure diagrams for the varying roll diameters for the stated conditions. Comparison of the two figures shows that Curve ① is not altered since its magnitude is such as to be unaffected by either

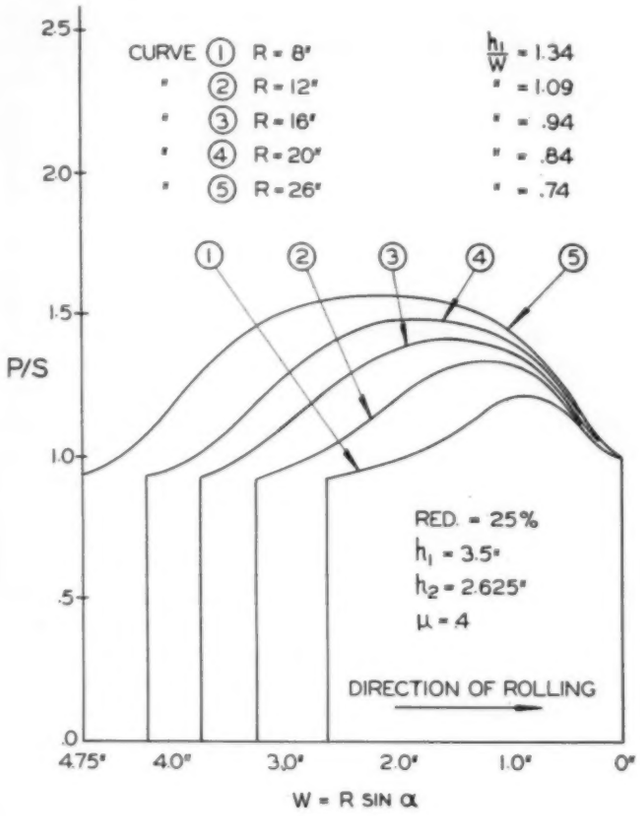


Figure 20 — Pressure diagrams for variable roll diameters when the criterion for sticking is $\mu P = S/2$.

of the two criterions for sticking. The pressure peaks of Curves ② to ⑤, inclusive, of Figure 20 are reduced and broadened in contrast with the corresponding curves of Figure 19. In Figure 20, as in the prior illustration, roll pressures increase with increased roll diameters and in this general respect conform with current theories of rolling.

From Figure 18 and Equation (24), the approximate tensile stress in the cross section of the entry plane is:

$$\text{Tensile stress} = \frac{2\,\mu P_A \cos\theta_A\, l}{h_1}$$

Solving the equation for the curves in Figure 20, the results for the varying roll diameters are:

Roll diam, in.	*Tensile stress*
16	0.442 S
24	0.333 S
32	0.274 S
40	0.260 S
52	0.220 S

The foregoing is a mathematical verification of the third paragraph of the author's theory. Figures 19 and 20 illustrate the higher roll pressures coincident with larger roll diameters while decreasing tensile stresses with increasing roll diameters are coincident with lesser tearing tendencies. The latter conclusion also has practical verification at South works where some tonnage of identical grades is rolled from common ingot sizes to common slab sizes on a 54-in. mill as well as on a 44-in. mill. Soaking pit installations are essentially identical; both conform to the same stipulated heating practices and the average time increment from draw to roll is also practically identical. Both mills have individual 5000-hp motors on each roll. The essential difference between the two units is in roll diameters. The conditioning surface removal on the 54-in. mill slab product is consistently slightly less than that on like 44-in. mill product. Conditioning for both units is done in the conditioning yard of another subsidiary plant.

ACKNOWLEDGMENTS

The author is especially indebted to the following three members of the South works organization: Mr. Horace E. Seely, Jr., for checking the derivation of the equations, for the many helpful suggestions which he provided in connection with the mathematical aspects of the paper, and for the working out of all the multitudinous calculations required for the formulation of the graphs presented; Mr. Carl W. Larson for the actual preparation of all the sketches and graphs presented; Mr. James D. Banks for the meticulous stenographic work required to convert the paper into presentable form.

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DISCUSSION

PRESENTED BY

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J. D. KELLER, Consulting Engineer, Associated Engineers, Pittsburgh, Pa.

J. H. Hitchcock: We are fortunate that Mr. Mican, after observing the results which followed the installation of knurled rolls, was curious enough to seek a rational explanation, and courageous enough to carry his quest through detailed mechanical and mathematical reasoning. It is from such intellectual labor as this, coupled with experiment, that the frontier of knowledge in this field can be extended.

In an effort to understand the author's work, I have attempted to set down in simple terms the successive steps in this derivation, and perhaps a brief enumeration of these steps will assist other students of this paper. These steps are as follows:

1. The horizontal forces produced by sliding friction between material and rolls are expressed by Siebel's equations.
2. The horizontal frictional forces are divided by the thickness of the bar to determine average values of horizontal stress in the bar.
3. The shear stress theory is employed to evaluate the ratios of radial and vertical pressure to compressive strength, using the average values of horizontal stress.
4. For various values of friction coefficient, several pairs of angles (β_3 and β_4) are so determined that equal and opposite horizontal forces are applied at the two angles of each pair.
5. The equations proposed by Prandtl are transposed to define the distribution of normal pressure within zones in which no sliding occurs between material and rolls.
6. The suggestion of Orowan that slipping ceases when surface friction exceeds the shear strength of the material is adopted to define one criterion of "sticking," or zero slip; and another criterion of zero slip is proposed, for a condition of restricted spreading, in terms of surface friction equal to double the shear strength of the material.

This paper commands respect for its thoughtful and imaginative combination of previous information to produce a new set of relations. However, there are several steps which I believe are open to question, and which cast some doubt upon the validity of the results. First I refer to the use of average horizontal stress to determine the radial pressure distribution. This assumes implicitly that the radial pressure distribution is independent of the stress distribution and flow pattern through the thickness of the bar. Actually the rate and direction of motion and the horizontal stress in the material, along any vertical plane in the zone of contact, must be non-uniform in most hot rolling operations, and the pattern of these factors undoubtedly affects the distribution of radial pressure. This point emphasizes also the inadequacy of one assumption which is fundamental to the theories of Siebel, von Karman, and the author; namely, that sections of the bar which were plane before rolling remain plane after rolling. Experimental evidence from many sources demonstrates that this condition is seldom fulfilled; several references of this character are cited by Underwood.(1)

An equally vital objection lies in the transposition of Prandtl's equations to define the distribution of normal pressure within zones in which no sliding occurs. Prandtl's equations portray in a linear distribution the normal pressure exerted by plane parallel plates upon a plastic body, as the author shows correctly in Figure 6a. The author's transposition of this relation to rolling, as shown in Figure 6b, implies that no sliding occurs along the vertical planes defined by angles β_3 and β_4, that the plastic material in these planes behaves exactly like Prandtl's plates, and that Prandtl's horizontal pressures t are transmitted to the rolls in a zone which also is characterized by the absence of sliding. Because these conditions are not fulfilled in the rolling process, I believe this transposition is unjustified. By some exercise of imagination, Prandtl's equations might be applied to rolling without transposition, by regarding the plates as representing a portion of the roll surface on which no sliding occurs. As reported by Orowan and Underwood, Nadai considered this, but rejected it because the rolls are not plane and parallel surfaces. He then developed a modification for plane but non-parallel plates, and derived stress relations for flow in the direction of convergence. Of this Underwood says: "The solution applies only to flow toward the apex ....., only to small angles of inclination of the plates, and this limits the application ..... to small angles of contact."

The author's introduction of an arbitrary second criterion of "sticking," or zero slip, also seems to me to lack justification. It is easy to understand that slipping between the surfaces of material and rolls will cease when the frictional resistance to slipping at the surface exceeds the resistance imposed to slipping within the material. The latter resistance Orowan chose to define as the shear strength of the material. Mr. Mican accepts this value for a condition of free spreading, and proposes another value twice as great for the condition of restrained spreading. Reasoning tells us that the resistance to slipping within the material cannot be less than the fundamental shear strength of the material, and that this value should apply only when flow can occur without external restraint in all directions except that of compression. Reasoning also suggests that the resistance to internal slipping can be increased in any desired amount by the selective addition of external restraint. Actually no hot rolling operation is wholly free from external restraint; consequently the resistance to internal slipping probably must always exceed the fundamental shear strength of the material. However, there appears to be no justification for the arbitrary selection of a value equal to twice the shear strength for a condition of restricted spreading.

In these remarks a distinction probably should be drawn between the internal slipping which is inherent in any process of plastic deformation, involving intercrystalline motion along slip planes, and the additional displacements which result from external and extraneous influences such as surface friction. Both types of motion occur in the same manner, but there is an important distinction between them; the first is essential to the change of shape for which the process is intended, while the latter is unnecessary, though unavoidable in some degree. An interesting discussion of this point was presented before the AISE by Holmquist, who was concerned with the piercing of tubes, and who characterized the two types of motion as "basic" and "redundant." See "Investigation Of The Piercing Process By Means Of Model Wax Billets," 1952 Proceedings of the AISE p 791. The redundant deformations will always remain with us in some degree unless a means is found to produce plastic deformation without external friction.

The author's distinction between the "apparent" and "actual" neutral angles leads to a comment which I have had in mind for some time. The concept of a neutral point or neutral plane is necessarily involved in every study of rolling theory, but not all writers on this subject agree in definition and use of this concept. Trinks in his book "Roll Pass Design" — Vol I defined the neutral point as the point at which the speeds of bar and roll are equal, and I am reasonably sure that he had in mind only the surface speed of the bar. Underwood defined a neutral point at which the resultant horizontal forces acting on opposite sides of the neutral point are equal and opposite. In this he followed Siebel, who also defined the neutral point by equilibrium of horizontal forces. If only one point of zero slip exists between rolls and bar, all of these definitions ostensibly identify the same point, and for this condition Mican accepts this definition. However, the neutral point so defined cannot be used in a relation involving forward slip without invoking the usually false assumption that all parts of the bar in a vertical plane through the neutral point move at the same speed. For use in relation to forward slip, a neutral plane might be defined as a vertical plane in which the average speed of the bar is equal to roll speed. Such a plane would not ordinarily include the neutral point identified by the previous definitions. For frictional conditions such that the rolls grip the bar without slip over a zone of appreciable length in the arc of contact, Underwood defines a neutral plane "which coincides with the plane of maximum radial roll pressure," while Mican selects the mid-point of the no-slip zone. These are not necessarily coincident, and neither one necessarily bears an exact relation to forward slip.

The author's conclusion that rolling pressure diminishes with increasing coefficient of friction in the range from 0.3 to 0.55 I find extremely difficult to accept, and I believe that the origin of this apparent misconception lies principally in the unjustified transposition of Prandtl's equations, and also in neglect of the nonuniform pattern of flow and stress through the thickness of the material. Perhaps subsequent study will lead to a different and more readily acceptable conclusion. Certainly the rolling pressure increases steadily with increasing friction as long as slipping occurs over most of the arc of contact. When friction rises to the stage at which external slipping is prevented over an appreciable part of the contact arc, further increase of friction perhaps will not affect the pressure gradient within the no-slip zone; but the rolling pressure must still increase because of the increased frictional forces outside the no-slip zone, and the additional internal displacements which, together with the effects of sliding friction at the surface, lead to a higher level of pressure within the no-slip zone. For a set of rolling conditions which remain constant except for surface friction, I believe that the maximum rolling pressure will be found analytically when the zone of zero slip extends over the entire length of contact. Whether this situation can actually occur in practice remains to be determined.

Before concluding this discussion, I want to ask the author a specific question regarding the figures stated for kilowatt-hours per ton with and without knurled rolls. I assume these figures were obtained by dividing the total power consumed over a considerable period of time by the tons of product rolled in the same period. Will the author please indicate whether this assumption is correct; and supply enough information regarding the rolling practices to show that the operations with plain rolls and knurled rolls are truly comparable?

In conclusion, I want to repeat my congratulations to Mr. Mican for this very creditable work. My comments are not to be regarded as destructive criticism, but are intended to emphasize the fact that there is still much to be learned about the rolling process and that further study and experiment by Mr. Mican and others interested in this subject should be encouraged for this purpose.

M. D. Stone: Mr. Mican's paper represents the type of thing that I think should be done much more in the steel industry, by the operators and engineers, who are associated with the operation, as has been done in the past. The subject justifies the analysis and type of work that Mr. Mican has done, all too little of which has been done in this country. Mr. Hitchcock's analysis indicates he has apparently gone over the paper in considerable detail. The thing I would like to comment on is his last point. In a comparable field, the forging field, where a considerable amount of readily checkable data has been taken, on the pressure required with forged discs and flat slabs, I believe there is no evidence that as the friction increased that the pressure decreased.

G. S. Mican: We thank Mr. Hitchcock and Dr. Stone for the constructive criticisms which they have offered on this paper. Mr. Hitchcock questions the effect of several steps on the validity of the results attained. He first questions the use of average horizontal stress to determine radial pressure distribution on the basis that this condition is seldom fulfilled in the hot rolling process. He recognizes that the use of average stress is merely a logical development from the basic assumption of rectilinear deformation which is likewise fundamental to the theories of Siebel and von Karman.

Mr. Hitchcock's reference to experimental evidence(1) contains several illustrations (Figures 29a, 29b on pages 63, 64, and Figure 36, page 73 of reference) showing that initially inscribed vertical lines and vertical end contours may bend either forward or backward with respect to the direction of rolling, dependent on the rolling conditions. In a prior paper(7) the author showed that for a wide range of steel grades, the principal

determinant for end contours and metal flow was the stock height to effective die width ratio. Initially rectilinear hot steel stock passed through rolls will develop the same type of end contour for lead and back ends. When the lead end contour is concave, the back end contour is also concave. When the lead end contour is convex, the back end contour is also convex. For the convex condition, for instance, initially vertical lines near the lead end bend forward with respect to the direction of rolling; and initially vertical lines near the back end bend backward with respect to the direction of rolling. Some intermediate portion of the length of the stock must undergo rectilinear deformation to accomplish flow reversal. Figure 21 is a simple graphic illustration of the flow principles described. Based on the foregoing, the author believes that rather than being a condition seldom fulfilled, rectilinear deformation is a condition which is fulfilled for some portion of every pass in hot flat rolling.

Mr. Hitchcock further questions the use of average horizontal stress to determine radial stress distribution on the basis that nonhomogeneous deformation implies non-uniform rather than uniform horizontal stress distribution and must affect radial pressure distribution. The deformation pattern which reverses from the lead end to the back end convexity is common to the hot rolling of plates and strip on continuous mills. Many roll separating force recordings have been made on both a test and a practical installation basis. Many power recordings on high-speed recording charts have also been made on both a test and a practical installation basis. If significant differences in radial pressure distribution were associated with degrees of variation from rectilinear deformation, such difference trends should be evident in the length of the stock on the recordings cited. To the best of the author's knowledge, no such difference trends have been observed. It is also of interest to note that pressure diagrams based on von Karman's theory (rectilinear deformation) and Orowan's theory (nonhomogeneous deformation) and shown as Figure 128, page 281, by Underwood, have fairly close coincidence. For the reasons stated, it is believed that the use of average horizontal stress does not affect the validity of the results attained in this work.

A third objection pertains to the transposition of Prandtl's equations to define the distribution of normal pressure within zones in which no slip relative to the rolls occurs. The primary objection is based on the fact that the author considered the bounding planes of the no-slip zone as rigid as the plates in the fundamental Prandtl condition. The secondary objection questioning the premise of no slip along the bounding planes appears to be contingent on the primary objection. The author assumes that no slip is an obvious condition with the premise of rigid planes and is a speculative question only with the premise of non-rigid planes. The author located the bounding planes mathematically with respect to forces acting on them so that the basic premise constitutes a condition of rigidity. Since the forces acting on the planes are equal, opposite and uniformly distributed, there are no unbalanced forces acting to cause flexure of the planes. The author concedes that the question may be considered speculative in a physical sense on the basis that direct experimental evidence cannot be secured to verify the mathematical premise. The following mathematical observations, however, are not speculative:

1. The highest values of the normal force (t) are derived from the premise of rigid bounding planes and the application of the Prandtl equations.
2. The assumption of flexing bounding planes could result only in the derivation of relatively lower values of the normal force (t).

Consequently, if the author's understanding of Mr. Hitchcock's concepts relative to the bounding planes were applied, they would tend to overemphasize rather than detract from the validity of the results of this work.

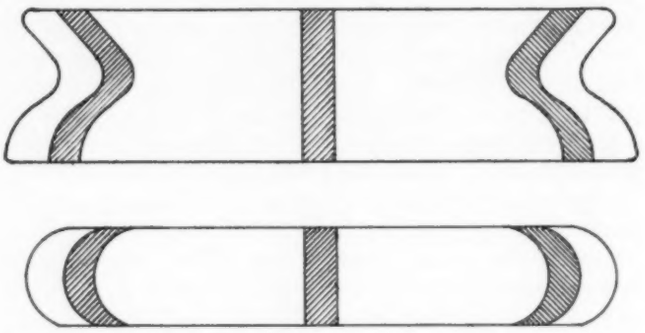

Figure 21 — Top shows end contours and originally rectilinear sections at lead, intermediate and back ends, shown after a rolling reduction on originally rectilinear stock under a rolling condition of stock height to effective die width ratio greater than two. Direction of rolling is immaterial. Bottom shows end contours and originally rectilinear sections at lead, intermediate and back ends shown after a rolling reduction on originally rectilinear stock under a rolling condition of stock height to effective die width ratio less than two. Direction of rolling is immaterial.

Another objection pertains to the introduction of a second criterion of "sticking" for the condition of totally restricted spread. An experiment was conducted on a maintenance shop forge press of 250-ton nominal capacity. Since steam lines and steam supply are adequate, steam pressures to the intensifier are uniform and consequently the maximum power of the press can be repetitively developed with reasonable accuracy. A heated 3-inch cube was compressed in a trough die with the full power of the press. With spread totally restricted in one direction, the final thickness was 1.53 inches. With a nominal contact area of 17.64 square inches, the maximum stress developed was $250 \div 17.55 = 14.2$ tons per square inch. A 4-inch cube was compressed between open dies with the full power of the press to a final thickness of 1.51 inches. With a nominal contact area of 42.38 square inches, the maximum stress developed was $250 \div 42.38 = 5.9$ tons per square inch. If the criterion of free spread is taken as $S/2 = 5.9$ tons per square inch, then the criterion for the condition of fully restricted spread is $\frac{14.2}{5.9} \times \frac{S}{2} = 1.2S$. It is recognized that by reason of larger volume and lesser heat abstraction, the 4-inch cube test finished at a higher temperature than the 3-inch cube test. It is quite evident to the author that experiments conducted on a more scientific basis could only result in a closer experimental verification that the criterion of "sticking" is in the range of $S/2$ to S.

Mr. Hitchcock states that he finds it extremely difficult to accept the author's conclusion that rolling pressure diminishes with increasing coefficient of friction in the range of 0.3 to 0.55. The reconciliation of the author's mathematical results with physical concepts should not be difficult to accept. As generally constructed, hot rolling pressure diagrams attain their variable forms because of the accumulative effects of the fluctuating values of only two variables: the coefficient of friction and the distance through which it acts in the arc of roll contact.

The diagrams must approach the flat base line of the compressive strength of the rolled material when either the coefficient of friction or the distance through which it acts approach zero. Everyone accepts the flat curve when the coefficient of friction approaches zero. Why should it be any more difficult to accept the flat curve when the distance through which it acts approaches zero? Orowan determined 0.64 as the value of the coefficient of friction at which sticking occurs throughout the arc of roll contact. The author determined a corresponding value range of 0.51 to 0.59 with the specific applicable value in the range being dependent on the particular rolling conditions considered. As the coefficient of friction approaches values that result in sticking throughout the arc of contact, the distance through which the force acts approaches zero. In view of the foregoing considerations, those who contend that peaks of hot rolling pressure diagrams must continue to increase with increasing coefficients of friction when other conditions are constant, must deny both the formation and the existence of zones of sticking and the broadening of those zones with increasing coefficients of friction.

Mr. Hitchcock is correct in his assumption as to the manner in which the quoted power consumption was derived. The figure associated with plain rolls was obtained by dividing the total power consumption of a two-year period by the total product tonnage of that period. The figure associated with the knurled rolls was correspondingly determined over a one-year period. The mill in question rolls a wide range of slab sizes for an 80-inch hot strip mill and a 96-inch continuous plate mill. The author was unable to find any practical way to evaluate mathematically the product mix for the two periods. It is the opinion of the author, in which his associates concur, that there was no significant change in product mix or in rolling practice for the two periods other than the introduction of the knurled rolls.

Dr. Stone observes that in hot forging, no evidence exists that pressure decreases with increasing coefficient of friction and that evidence indicates that pressure increases with increase of coefficient of friction. The author agrees with Dr. Stone at least with respect to forgings of a size that are wholly within the compressing die dimensions. In order to obtain rough hot forging checks on Polakowski's[8] work, we upset 3-inch diameter cylinders between die liners varying from smooth to 0.65 coefficient of friction. For each test the full power of a 250-ton press was developed. Thicknesses increased and diameters decreased with increased coefficients of friction. In other words, pressures increased with increased coefficients of friction within the range of the tests made. This condition of forging, however, differs from rolling. If the coefficient of friction is 0.65, in the forging of the 3-inch cylinders for instance, the original 3-inch face can "stick" to the dies; but as the contact area increases with compression, stock moves into die contact in sliding friction. We expect the resistance to increase with greater coefficients of friction. On the other hand, if a coefficient of 0.65 prevails in rolling, "sticking" occurs throughout the arc of roll contact; and there is no sliding friction between stock and rolls. Under this condition we would expect the pressure diagram to be the flat curve of the compressive strength of the stock. In other words, there is no contradiction between hot forging evidence and the results of this work.

J. D. Keller: The important feature of this paper is the attempt to take account of the fact that in the middle part of the arc of contact of the slab on the roll surfaces, no sliding or relative motion of the contacting surfaces occurs. In hot rolling, the presence of this no-slip region is often of importance, and in recent years it has been too much neglected. The assumptions made in the author's derivation, however, seem to the writer to be totally inadmissible. This refers particularly to Figure 5 of the paper.

The Prandtl, ("Fondements Mathématiques de la Théorie des Corps Plastiques Isotropes," by L. Prandtl and H. Geiringer, Memorial des Sciences Mathématiques, Paris, 1937) or Prandtl-Geiringer, mathematical theory of plastic flow of material compressed between parallel flat plates when no slippage occurs at the plate surfaces, at best seems questionable; for, (if the writer's understanding of it is correct), the family of cycloidal curves derived by Prandtl as representing the slip lines in the plastic material is derived on the assumption that the plates extend to infinity in either direction from a point taken as the center of contact, whereas actually the length of the equivalent plates is finite and usually no large multiple of the thickness of the material between the plates. Furthermore, neither the shape of the flow lines nor the pressure distribution over the plates seems to agree with the few test results available. (See the writer's paper on "Cold Rolling Strip," Part V, especially Figure 20, Steel, 1951, Feb. 19, March 5, 19, 26, May 14, July 9, 23, and August 13.)

But even assuming the Prandtl curves to be approximately correct, it would seem almost self-evident that the use made of them in the author's Figures 5, and 6b, cannot be right. The vertical parallel plates actuated by hydraulic pistons, shown in Figure 5, cannot correspond to the actual conditions, first because they require that the horizontal flow of the metal of the slab be uniform throughout the thickness, whereas actually the parts at the middle of the slab thickness have the greatest motion relative to the roll surface and those parts contacting the surface have no relative motion (if no slip occurs); second, because the Prandtl theory requires that the plastic material be perfectly free to flow in the direction at right angles to the plates (or up and down, in Figure 5), whereas actually any such flow is prevented by the rigid roll surfaces.

The author seems to be unaware of the work of Korber and Eichinger, who combined the Prandtl theory of deformation without slip; with the von Karman theory which applies when slip occurs. (See "Die Grundlagen der Bildsamen Verformung," by F. Korber

u. A. Eichinger, Mitt. Kaiser Wilhelm Inst. f. Eisenforschung, Abh. 395, 1940, Band XXII, Lieferung 5.) They showed how the length of what they called the "Haftgebiet," or region of no-slip, could be calculated. The writer utilized their work in his paper on "Cold Rolling Strip"(2) (Part I, especially Appendix A), but Korber and Eichinger's equations apply to hot rolling as well.

Using the Korber-Eichinger equations, the writer calculated the length of the no-slip region and the maximum pressure on the rolls, for the conditions of the author's Figure 14, in which $\frac{h_1}{W}=0.42$ and $\frac{h_2}{W}=0.243$. For the purpose of substituting the parallel flat plates of Korber instead of the actual curved roll surfaces, the mean value of $\frac{h}{W}$ was taken to be 0.302, which means that the contact length is 3.31 times the mean thickness of the slab between the rolls. The following tabulation gives a comparison of these results with the values obtained from the author's Figure 14.

Coefficient of friction	No-slip region as a fraction of contact length		Maximum pressure as a multiple of S	
	Mican, Figure 14	Korber & Eichinger	Mican, Figure 14	Korber & Eichinger
0.2	0.34 (about)	0.124	2.50	1.87
0.3	0.47 (about)	0.226	3.80	2.46
0.5	0.86 (about)	0.415	3.25	3.47
Infinite	.....	1.00	.....	6.48

The Korber-Eichinger values show no peak of pressure at a friction coefficient of 0.30; instead, the curve of P_{max} rises smoothly with increasing μ, becoming asymptotic to a pressure of 6.48 S as a limit (for $\frac{h}{W}=0.302$) when $\mu=\infty$ and the no-slip region extends over the whole contact length.

Even though the results calculated for the parallel flat plates are not strictly correct in numerical magnitude for the actual curved roll surfaces, it is believed that the general shape of the curve of pressure versus coefficient of friction must be the same for both. If so, the author's finding of a decrease of pressure when the friction coefficient exceeds 0.30 cannot be correct.

Of the observed results as stated in the paper, two which would be expected to result from knurling are decrease of surface tearing, and decrease of roll wear. Why the roll breakage and the power consumption should be decreased is not so clear. Perhaps the former results from reduction of stresses due to thermal expansion and contraction, as in the case of corrugated ingot surfaces to which the author compares the knurled roll surfaces. As to power consumption, the power absorbed by the sliding of the slab surfaces on the roll surfaces would probably be reduced by the knurling (it is evident that this would be reduced to zero if the friction coefficient were infinite and the surfaces did not slip at all), but the work of internal deformation within the slab itself would be increased. The writer would have expected the net result to be at least some increase of power consumption in the case of knurled rolls, if both the knurled and the plain rolls had been of the same diameter.

The reduction of surface tearing can be clearly explained on the basis of Siebel's graphical representation, one example of which is given in the author's Figure 3. If the angle of contact α (referring to that figure) is larger than the friction angle ρ, as may happen with smooth rolls, the sloping straight line A-F-C-G will lie above the arc A-E-D from A to some point to the right thereof, between A and D; this means that from A to this point of intersection of the sloping line with the arc, the component of the roll pressure tending to push the slab out of the "nip" of the rolls toward the left is greater than the friction force tending to pull it in. The result is horizontal tensile stress in the slab in this region, and this is the cause of those surface tears which occur within the contact length. Knurling the roll surface increases the friction and changes the longitudinal stress in the slab from tension to compression.

It will at once be objected that if the friction angle ρ in the author's Figure 3 were smaller than the angle α of the roll surface at the point of entry, the slab could not be entered; the rolls would not "bite." However, it must be remembered that the friction coefficient decreases with increase of speed of sliding, as mentioned by the author and as shown for example in the writer's paper, Part IV, Figure 18. (The writer believes that Tafel's data are unreliable as regards the effect of speed on the friction coefficient). In a slabbing mill, the roll speed is purposely reduced in order to enter the slab between the rolls, and the coefficient of friction, almost corresponding to static friction, is high. After the slab has been entered and the mill has been brought up to speed, the increased velocity of slipping of the slab on the roll surfaces reduces the coefficient of friction, and the tensile stress in the slab can then appear.

The existence and effects of such tensile stresses were clearly evident in tests made by Professor Trinks and the writer about 1935, rolling bars of beeswax between sectors of wooden rolls having about 20 feet equivalent diameter. When the smooth varnished wood surfaces were oiled after the front end of the beeswax slab had been entered between them, continuation of the rolling not only tore the surface but actually pulled the slab apart, with necking-down such as occurs in a tensile test.

The results of others of these experiments with rolling beeswax raise the question, whether in eliminating surface tears by knurling the rolls, one may not be jumping from the frying pan into the fire, by inducing internal tearing of the steel, due to the much more severe shearing deformations produced by preventing the slab surface from sliding while extruding the material in the middle part of the slab thickness from between the constrained surface layers. Such internal tears would be much harder to detect than surface tears. In the beeswax experiments, when coarse emery paper was fastened to the wooden roll surfaces, the friction was so great that no sliding of the surface layers could occur, but the middle part of the thickness of the beeswax bar was not only sheared off so that it was totally detached from the surface layers, but was so full of cracks running at angles to the vertical that it was totally disintegrated.

Granted that beeswax has less ductility than steel, still the same general action occurs in both when being rolled; and weak spots inside the steel slab which might remain whole when rolled between smooth rolls, might be ruptured to form actual internal tears under the much more drastic deformation produced by knurled rolls.

Again under certain conditions, surface tears can occur not only when the steel is in contact with the rolls but even before it enters into contact. Non-uniformity of temperature throughout the slab thickness must be considered here. Just before the slab is taken from the soaking pit, it is usually given a "wash heat" which results in a thin molten layer of metallic iron and oxide dripping from the surface. (The purpose is to wash off scale, mold splashes and other adhering impurities). Hence, even allowing for some surface cooling during the descaling, in the first pass in the mill, the surface layers of the slab are usually appreciably hotter than the core, and hence more easily deformed; the core is pulled into the rolls with less than average elongation while the surface layers hang back and tend to pile up just before the beginning of contact with the rolls, so that the slab tends to become slightly thicker at that place. (The writer has never observed this, but others have reported its occurrence). Since the surface layers are not only soft, but are under longitudinal compression, surface tears do not occur at this place, in the early passes.

In later passes, however, the temperature conditions are reversed; the surface layers of the slab, by contact with the cold roll-surfaces, have lost much heat and have become cooler than the core which has lost little heat. The core now being softer than the surface layers elongates more than these, and is extruded backward relative to them. (This is shown by tests in which lines had previously been scribed on the sides). The shearing forces try to carry the surface layers along with the core, and this produces longitudinal tensile stress in those layers just before they contact the rolls, sometimes resulting in surface tears occurring here. It is not evident that knurling the rolls would prevent tears produced in this way; on the contrary, because of its accentuation of the extrusion effect, it would be expected to increase the likelihood of such tears occurring.

In connection with this matter of tearing in rolling, much might be learned by study of the distortion of a network of parallel straight vertical and horizontal lines scribed on the sides of slabs or bars before rolling. Many such rolling tests were shown by Professor Trinks in a series of articles published in Blast Furnace & Steel Plant in the years 1914 to 1916; though old, they are by no means outdated, and will well repay careful study.

Two more items in the present paper should be pointed out as incorrect. One is the calculation of temperature drop of the slab in the roll contact. The author seems not to have known of the careful analysis of this temperature drop in Trinks "Roll Pass Design," Vol. II, pp. 201-210, where it is shown that by far the greatest part of the total temperature drop in the rolling process is due to the contact with the cold surfaces of the rolls; the drop due to radiation and convection usually being small compared to this.

The second item is the calculation of the tensile stress, in connection with the author's Figure 18; this is believed to be wholly incorrect because the horizontal components of the pressures normal to the roll surface have been neglected.

The paper nevertheless represents a laudable effort, in a field in which all too little has been done, and the purpose of pointing out its defects is to assist the author in any extension of the work.

G. S. Mican: The author is very appreciative of the thorough review that Mr. Keller gave his paper and the extent to which he expressed his comments.

Mr. Keller first expresses the opinion that the Prandtl or Prandtl-Geiringer mathematical theory of plastic flow of material compressed between parallel flat plates when no slippage occurs at the plate surfaces, at best seems questionable. The author acknowledges that Mr. Keller is authoritative enough in this field to properly raise such a fundamental question. Contrarily, the author concedes that he is not sufficiently authoritative to enter into a discussion of the merits of such a fundamental question. We have noted, however, that some other authoritative writers in this field such as Nádai([13])* and Orowan ([4]) have derived and used the Prandtl equations, without serious question of resulting accuracy, under the conditions of finite dimensions of the compressing plates. Orowan, in the development of his theory of rolling, employed as a basic premise the Prandtl equation, derived by using finite dimensions of the compressing plates and modified by Nádai to apply to inclined planes. Does the use of such a premise necessarily make the validity of his entire work incorrect?

Mr. Keller points out that even if the Prandtl curves were approximately correct, it would seem almost self-evident that the use made of them in the author's Figures 5 and 6b, cannot be right because the vertical parallel plates actuated by hydraulic pistons, shown in Figure 5, cannot correspond to the actual conditions. The author's reply to this observation is practically the same as made with respect to Mr. Hitchcock's corresponding observation; namely,

1. The author clearly stated rectilinear deformation as an assumption.
2. Based on the foregoing, the position of the parallel plates was mathematically derived from the stress condition.
3. An assumption of curved plates, suggested by Mr. Keller in lieu of parallel plates as mathematically determined, would serve to overemphasize rather than detract from the validity of the author's work.
4. Rectilinear deformation is not a rare phenomenon in hot rolling, since it must occur in some portions of a large proportion of hot rolling passes.
5. If an appreciable difference in rolling pressure is incident to nonhomogeneous deformation as contrasted to rectilinear deformation, it has not been observed on production-line instrumentation sensitive enough to register it.

Mr. Keller's second premise of objection to the author's use of the Prandtl equations is based on his statement that the Prandtl theory requires that the plastic material be perfectly free to flow in the direction

*Numbers in parentheses refer to references at end of main article, or if new to discussion, to references at end of this discussion.

at right angles to the compressing plates (or up and down, in Figure 5). Is this stipulation a complete contradiction of the previously stated basic premise that the compressing plates must be of infinite dimensions? Can any force be conceived that, when applied to compressing plates of infinite dimensions, would result in free flow of the free ends of the plastic materials? The author believes that under the preceding condition, no flow would result, but a stress condition would develop that would be identical with a condition of rigid resistance to plastic flow at a finite distance from the center-line of the force application to the compressing plates.

The author agrees that infinite dimensions of compressing plates is a basic premise of the Prandtl derivation. He believes that this condition is the equivalent of rigid resistance to the plastic material at finite distances from the center-line of force application. For this reason it is felt that the illustration of the Prandtl condition indicated as Figure 112 by Underwood(1) is valid and that the accompanying equations are likewise correct. For the same reason it is believed that usage of the equations for the condition shown as Figure 5 by the author is also right. The usage of the Prandtl equations by others, under conditions of both finite dimensions and free end flow, is much more questionable.

Mr. Keller refers to the work of Korber and Eichinger,(14) who combined the Prandtl theory of deformation without slip with the von Karman theory, which applies when slip occurs. Mr. Keller implies confidence in the validity of this work, and the author is familiar with his utilization of their work in his very excellent paper on "Cold Rolling Strip."(15) However, in view of the fundamental question he asked with respect to the Prandtl equations, could they have been absolutely right and the author absolutely wrong in the use of those equations? Since the von Karman theory is based on rectilinear deformation, could they have also been absolutely right and the author absolutely wrong in the use of this assumption?

The author is very appreciative of Mr. Keller's interest as evidenced by his calculation of the comparative values of the no-slip region as a fraction of contact length and maximum pressure as a multiple of S. It is quite difficult to comprehend the physical significance of a value of infinity for the coefficient of friction. This value apparently had to be used in the Korber and Eichinger calculations to arrive at a condition of no slip throughout the arc of roll contact. It is difficult to comprehend the physical significance of any value greater than unity for the coefficient of friction. In contrast, Orowan derived a value of 0.64 for a condition of no slip. The latter value compares with a range of 0.5 to 0.58, derived by the author for various rolling conditions.

The fact that Korber and Eichinger showed how the length of the no-slip arc could be calculated, does not necessarily imply superior comparative merit for their work. The author also calculated the length of the no-slip arc and its exact location. In addition, when assuming nonhomogeneous deformation, the author was able to determine mathematically the contours of the so-called "nonplastic zones" for various rolling conditions. The latter work is too lengthy and complex to describe in this discussion and would constitute a paper in itself.

To emphasize one section of my paper, the comparison of actual results of surface tearing, power consumption, roll wear, and roll breakage, was based on the same diameters of both plain and knurled rolls.

Mr. Keller's explanations of why there should be less surface tearing with knurled rolls than with plain rolls are both logical and interesting. The essential difference between Mr. Keller's and the author's explanations is that while the author also derived a logical explanation, he further verified it by mathematical stress value determinations.

With reference to Mr. Keller's comments on the temperature drop within the pass, it may be stated that the details of the calculation in no way affect the validity of the author's work. On the other hand, Mr. Keller's statement that the temperature drop due to radiation and convection is negligible in contrast with the drop due to contact with the rolls, is subject to reexamination. The ratio of the temperature drop attributable to the two broad causes mentioned, is greatly influenced by the length of stock being rolled. This is specifically illustrated by two calculated examples in Trinks' "Roll Pass Design," Vol. I, pages 49 - 56. In Case I, the initial length of stock is assumed to be 4 feet, the temperature drop in the pass occasioned by roll contact was calculated to be 16.0 F, and the temperature drop per pass caused by radiation was calculated to be 15.1 F. In Case II, the initial length of stock is assumed to be 100 feet, the temperature drop in the pass by reason of roll contact was again calculated to be 16.0 F; and the temperature drop per pass due to radiation was computed to be 71.2 F. Conditions other than the length of stock in the two cases were held constant.

Mr. Keller may be correct in his suggestion that the horizontal component of the normal force be considered in connection with Figure 18 and the derivation of Equation (24) for the determination of tensile stress. When this component is added, Equation (24) changes from:

$$\text{Tensile stress} = \frac{2\mu\ P_A \cos\theta_A l}{h_1} \qquad (24)$$

to

$$\text{Tensile stress} = \frac{2P_A l(\mu \cos\theta_A + \sin\theta_A)}{h_1} \qquad (25)$$

The determinations for the two specific curves of Figure 15 cited are:

		Mican	Modified per J. D. Keller
$\mu = 0.3$	Tensile stress =	0.335 S	0.432 S
$\mu = 0.5$	Tensile stress =	0.037 S	0.045 S

The determinations for the curves in Figure 20 applying to the varying roll diameters become:

Roll diameter, in.	Tensile stress Mican	Modified per J. D. Keller
16	0.442 S	0.682 S
24	0.333 S	0.517 S
32	0.274 S	0.414 S
40	0.260 S	0.382 S
52	0.220 S	0.314 S

The author agrees with Mr. Keller's observation that

when other conditions are held constant, a variation in the coefficient of friction will result in a redistribution of both surface and interior stresses in the rolled stock. The author accepts the results of Mr. Keller's beeswax experiments, but wishes to point out that the equivalent roll diameter of 20 feet in relation to stock height is out of all proportion with actual ingot-to-slab rolling practices. Within practical ranges, the effect of the coefficient of friction on the distribution of internal stress is negligible in contrast to the effect of stock height to effective die-width ratios. A similar ratio of effect prevails with regard to many other actual operating factors and the coefficient of friction.

The author has made many obsevations and stress, analyses in connection with the rolling of steel stock, including ingots. Figure 22 is an example of a complete break through an ingot, caused by accumulative internal stress resulting from improper rolling technique. The contour of one of the breaks is particularly in almost perfect conformance with a derived stress pattern relating cause with effect. Within limited chemistry ranges, the author can duplicate the breaks shown. With modified rolling techniques, accumulative internal stress can be held to a minimum and the breaks avoided. The foregoing effects can be achieved within the full practical range of the coefficient of friction. The preceding is only a partial and incomplete justification for the broad statements made concerning the relative effect of the coefficient of friction on internal stress. A more comprehensive treatment of this subject matter would constitute a paper in itself

In the introductory portion of his paper, the author acknowledged that he himself did not accept the results of his work as final proof of his theory. He stated that the work was subject to a broader range of test than could be covered in a single effort. What the author had particularly in mind was that although scientifically conducted physical tests would not be necessarily complex or extensive, he was not in a position to conduct such tests. Continued observation of practical rolling results has tended to confirm the author in his conviction in the correctness of his explanation. Scientific tests could be confined to the determination of total hot rolling pressures when all other conditions were held constant and the coefficient of friction was varied from minimum to approximately 0.6 values. If this work should serve to stimulate some who are in a position to conduct scientific tests, to do so, the author would consider the results of such tests as the most direct evidence that could be developed for the verification or the refutation of his theory.

Figure 22 — A 25 x 30-in. open-top ingot reduced to 23 x 25-in. when rolling was stopped because of ruptures shown. Ruptures were induced by accumulative internal stress due to improper rolling technique. Analysis was: C 0.88, Mn 0.76, S 0.024 and Si 0.28 per cent.

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THE ELECTRIC FURNACE WEST OF THE ROCKIES

By W. B. WALLIS
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Pittsburgh, Pa.

. . . . a buyer's market in steel will result in a demand for quality in steel which may best be met by the electric furnace . . . .

▲ IN discussing the development of steel production on the West Coast, this paper has been limited to consideration of the states of Washington, Oregon and California in contrast to other papers that have been given before which included also Utah and, in some instances, Colorado as a part of the western steel producing community. We want particularly to discuss the part the electric furnace has played in the steel development of the West.

Many engineers and operators agree that under most economic conditions existing in the United States it is possible to produce common quality steel from an electric furnace of the top charge arc type for less money than with an open hearth, provided always that the practice is 100 per cent cold charge.

COMPARISON COLD MELT PRACTICE — OPEN HEARTH AND ELECTRIC

In 1953, a very thorough study was made by Battelle Memorial Institute of the comparative economics of open hearth and electric furnaces for the production of low carbon steels. This report showed that in comparing an open hearth shop and an electric furnace shop, both of 250,000 tons annual ingot capacity working on cold charges, the electric furnace cost per net ton of ingots was $3.70 less than the open hearth costs. On a shop having 500,000 tons annual capacity cold charge, the electric furnace was $3.15 less per ton of ingots.

Subsequent to that report, Leo Reinartz, at a meeting of the American Iron & Steel Institute in December, 1953 in Philadelphia, read a paper on the electric furnace versus open hearth in cold metal shops in which he shows that the cost above on the electric furnace was about four dollars per ton of ingots higher than the open hearth, whereas the material cost for electric furnace steel is four dollars less per ton than for the open hearth, based on 1953 Pittsburgh prices of pig iron and scrap.

He further points out that the capital cost of an equivalent capacity electric furnace shop was about 60 per cent of that same capacity shop with the open hearth thus resulting in a lower carrying charge on the plant. When this figure was taken into consideration, together with cost above and material cost, he shows for the 250,000 net ton shop on cold melt practice $3.93 lower cost per ton of ingots in the electric shop, and the 500,000 net ton per year ingot capacity shop shows $2.59 per ton in favor of the electric furnace.

He points out that with cheap scrap in relation to pig iron, this differential may rise to eight or nine dollars per ton in favor of the arc furnace or, using figures of $36.00 per gross ton for pig iron and $43.00 per gross ton of scrap, in other words, a low cost pig iron with a high priced scrap, it shows for the electric furnace an advantage of 47¢ per ton on the 200,000 ton ingot shop whereas for a 500,000 ton shop the advantage is 87¢ in favor of the open hearth, all of the above being for cold charge practice.

PROGRESS OF THE ELECTRIC FURNACE

It has been only within the past ten years that serious consideration has been given to the top charge arc furnace as a producer of carbon steels from cold scrap charges. Some of the reasons for the inroads that the arc furnace has been making into this field are:

Its flexibility in being able to operate without serious

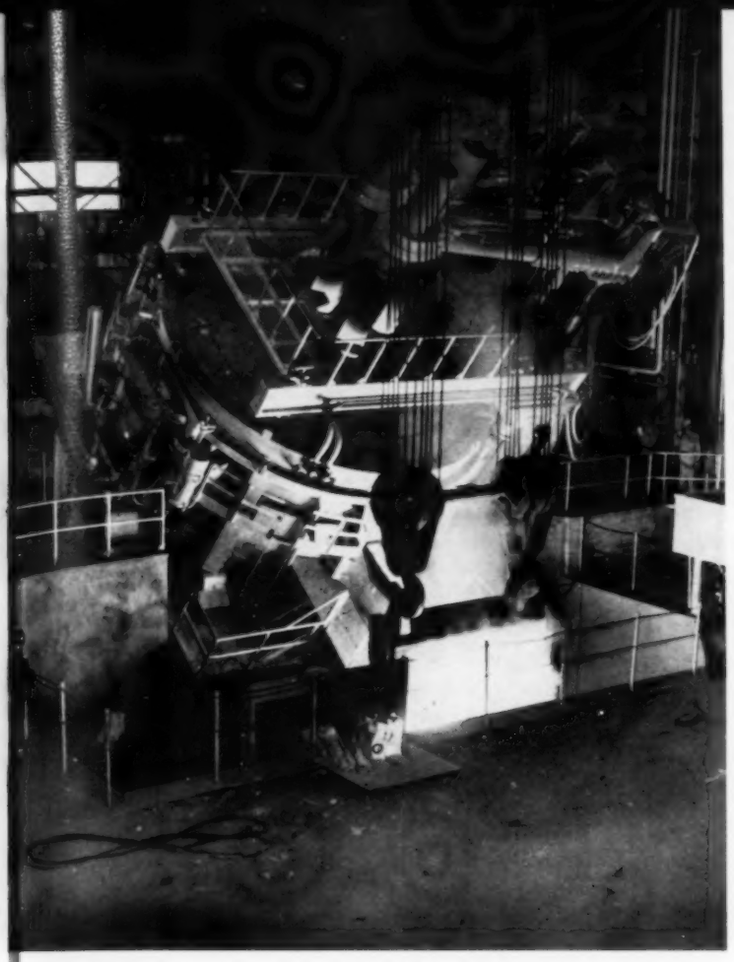


Figure 1 — The trend toward top charge in electric furnaces has greatly accelerated its efficiency.

consideration being given to shut-down periods. At the present time many electric furnaces are operating on a five day week with shut-downs for each Saturday and Sunday.

From a fuel standpoint, electric energy is one fuel that has not increased in cost in line with other types of fuels being used in the melting of steel. There has been a vast growth in this country in our utility systems and each year marks the introduction of improvements which effect greater and greater economies in the production of electricity. Power producing capacity has increased 34,000,000 kilowatts since the war and 9,200,000 kilowatts was added during 1953. Today no less than 98 per cent of our population is now connected to power lines. In connection with electricity as a fuel, it is one fuel that does not carry with it any sulphur.

Again, the quality of electrodes in the United States has been continually improving, and if question be raised on this point one has only to have a look at the electrode consumption on American furnaces operating in Europe on the same practice as used here in America but using European electrodes.

Again, the cost per ingot ton of capacity of an arc furnace shop is about 60 per cent of the cost of an equivalent capacity open hearth shop with correspondingly reduced carrying charges.

The percentage of availability of the arc furnace as against the open hearth is about 96 per cent for the electric and 92 per cent for the open hearth, which means that the electric furnace would be shut down 14.5 days during the year for refractory repairs while the open hearth would be shut down 29 days for repairs.

Again, the ingot yield from cold scrap charges on open hearth and electric will range from 93 per cent on the electric to 89 per cent on the open hearth, which, on a 250,000-ton shop means a difference of 10,000 tons of ingots per year in favor of the electric furnace.

From a heat transfer standpoint; that is, putting heat into the metal, the electric furnace is much more efficient than the open hearth. Battelle Memorial Institute, in their study of heat balances on the two types of equipment on cold scrap charges, shows heat content of the steel in the open hearth to be 25.8 per cent with the electric furnace 70.5 per cent. In other words, heat losses in the open hearth amount to 74.2 per cent and in the electric furnace 29.5 per cent. Reinartz figures the thermal efficiency of the arc furnace on cold metal practice at 78 per cent as against 31 per cent efficiency from the open hearth.

About 33 per cent of the heat applied to the open hearth is lost in stack gases, and the loss in stack gases is just about equivalent to the Btu required to make a ton of steel in the electric furnace; all of which points to the fact that in open hearth plants serious study should be given to the enormous amount of recoverable heat that is being wasted in these operations.

It should be here stated that even though the electric furnace uses only about 1,600,000 Btu per ton of ingots, whereas the open hearth uses 4,500,000 Btu, the cost of the 1,600,000 Btu for supplying electric energy is greater than the cost of 4,500,000 Btu required for open hearth steel melting. When there is added to the energy requirement of the electric furnace the cost of electrodes, the overall fuel cost of the electric furnace rises to about $4.00 a ton above that of the open hearth. Against this debit on the electric we have two credits; namely, the $4.00 a ton average lesser cost of charge for the electric furnace and, in addition, the lower carrying charges on investment resulting in an overall saving in favor of the electric furnace as outlined above.

TYPICAL ELECTRIC FURNACE INSTALLATION

Figure 1 shows a picture of a typical top charge 20-ft diameter electric furnace powered with a 25,000-kva transformer, a type that has been largely responsible for the inroads of the arc furnace into the open hearth field. This particular furnace, for the year 1953, operated at an average of 500 kwhr per ton with an electrode consumption of 10.5 pounds, the average power factor for the year being 81.2 per cent.

Operating figures available for last year on another 20-ft diameter furnace shows net tons per heat 97.8; net tons produced per hour 21.14; average power consumption 490 kwhr; average electrode consumption 9.59 pounds and ingot yield 95.57 per cent. It is interesting to note that this latter furnace is not running Saturday and Sunday.

Figure 2 shows a furnace of 18-ft diameter which, in the first ten months of 1953, produced 99,863 tons or an average of 9986 tons per month, the average size heat being 75 tons; the kwhr consumption 500; the electrode consumption 8.75 pounds and the yield 93.5 per cent. In this particular plant the open hearth superintendent, reviewing the 1952 operations, stated that the electric operated 94.5 per cent of all available hours

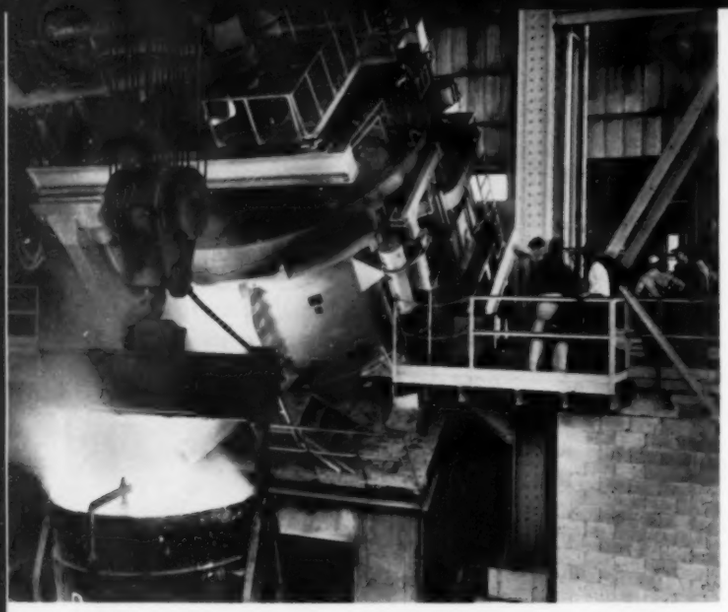


Figure 2 — This 18-ft electric furnace unit averages almost 10,000 tons per month.

and the three open hearth 86.5 per cent of all available hours.

The comparison of repair cost per ton of steel produced, taken over a seven month period in which the open hearths produced 100,603 net tons of ingots with an average repair cost of $3.35 per net ton showed the electric furnace producing 65,438 net tons at an average repair cost of $2.65 per net ton.

FUTURE ELECTRIC FURNACES

Figure 3 shows the growth in size of arc furnaces, there being at present two 24 ft-6 in. inside diameter furnaces and one 24 ft-0 in. inside diameter furnace in fabrication. These are all three-phase, three-electrode furnaces.

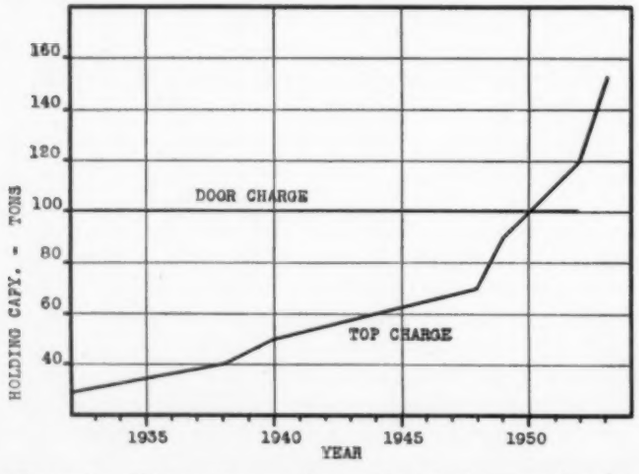


Figure 3 — The maximum size of electric furnaces has increased in top charge units and remains static for door charge units.

At this point it might be well to mention some discussion that has taken place relative to the desirability, on large furnaces, of utilizing a six-electrode furnace. This argument stems from observations made at a shop that installed a six-electrode door charge furnace 25 years ago, comparisons being made with a recently installed 20-ft top charge furnace in that shop.

We are inclined to believe that the particular shop has had plenty of time to work out all the "bugs" on the six electrode furnace operation in the 24-year period. The top-charge, 20-ft diameter furnace is the first top-charge furnace this shop has had. Not only that, it is the first high powered furnace that they have had and we do not feel that they have had, in the few months of operation, an opportunity to bring this equipment to its optimum economies in operation.

We would have preferred to have seen the paper presented after the top-charge furnace had been working in the shop for at least two years before being presented as a comparison with the six-electrode furnace. There are arguments for both the six-electrode furnace and for the three-electrode furnace but we are inclined to feel from our experience that we will continue on with the three-electrode design, until further evidence is presented.

It should be mentioned here that we have had experience beginning in 1936 with the installation of six-electrode furnaces for smelting operations and will continue to propose that type of furnace for large smelters.

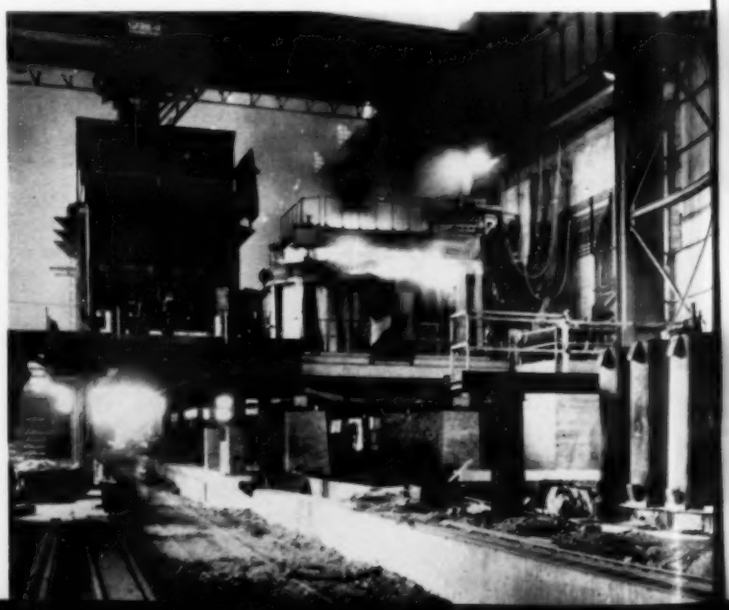
We are now building four 26 ft-4 in. diameter tilting furnaces of the three-electrode type and are prepared to offer 26-ft top charge furnaces powered with 50,000 kva.

Figure 4 shows the largest furnace at present in operation in the United States, this furnace being 22 ft in diameter, powered with a 36,000-kva transformer and operating on 125 ton heats, the rate of production being reported at 28 tons per hour. Two of these furnaces are installed with provisions being made for two additional in the shop.

Figure 5 shows the growth in size of transformers used with steel melting furnaces. The size of transformer back of door charge furnaces has remained largely at the level set for transformer capacities during World War II, the optimum having been the two transformers put back of the six-electrode furnaces in 1927.

The curve projected on transformer capacities is limited to the range that is in actual operation. In considering this curve I was interested in studying the 1947 report of the Electric Furnace Committee of the

Figure 4 — This 22-ft unit shown was believed to be the largest one in operation at the time of presentation of paper.



American Iron and Steel Institute which report emphasized that the maximum power that could be efficiently handled by one electrode was 4500 kw. Time passes quickly in an industry such as this.

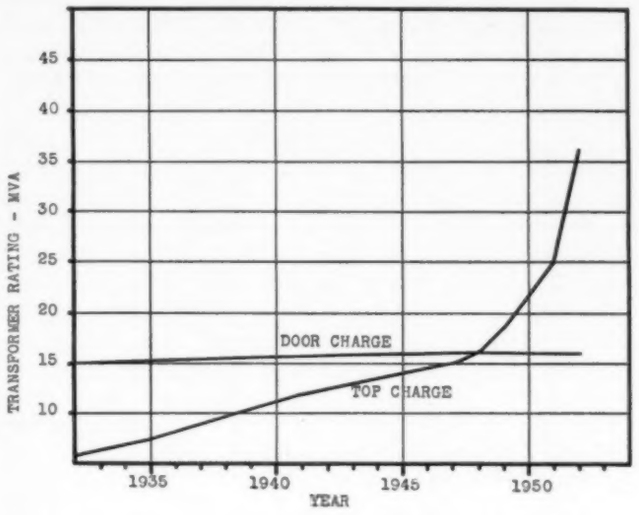


Figure 5 — Transformer ratings on electric furnaces are now up to 35,000 kva.

INDUCTION STIRRING

A very interesting development to steelmakers in the United States has been the installation of an induction stirrer on a 20-ft diameter top charge furnace equipped with a 20,000-kva substation. This stirrer has now been in operation for over a year. Officials of the company state that it is a bit too early to make positive statements as to all results, but there were certain statements that could be made, based on the experience during the past year, that indicated the following:

1. A more homogeneous bath.
2. The shipping yield was showing up 2.5 per cent better on the average and on high nickel steels 15 per cent better.
3. Much lower sulphurs were being obtained than heretofore and have been possible without going to extreme trouble; that is, on this furnace numerous heats are made with sulphurs ranging from 0.005 rising to 0.01 per cent. In comparison, duplicate furnaces without stirrers, on the same practice, were averaging around 0.015 per cent sulphur.
4. More representative samples of the bath were obtained to send to the laboratory.
5. Closer temperature control.
6. Closer chemical control.
7. Better ingot surface.

The speed of motion, when the stirrer was first started up, was four feet per second across the bottom of the furnace and two feet per second at the top of the bath. Since the stirrer has been put into operation, the speeds have been reduced to two feet per second across the bottom of the furnace and one foot per second at the top of the bath with no change having been noted in the metallurgical results.

This is the type of stirrer developed in Sweden of which a number of installations have been made on the continent. A contract has been made for the installation

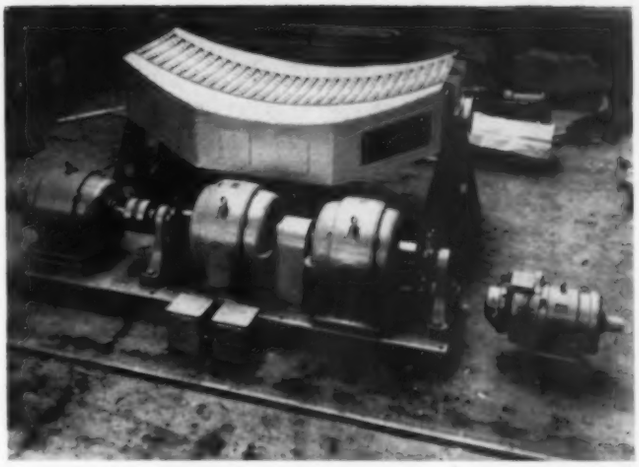


Figure 6 — Induction stirrer units in operation in this country are at present of the static type.

of a stirrer by a second of the steel producers in the United States.

The foregoing is a static type of stirrer attached to stainless steel furnace bottom. A competitive type of stirrer is now being offered in the states, this of the rotating type, but no installations have as yet been made.

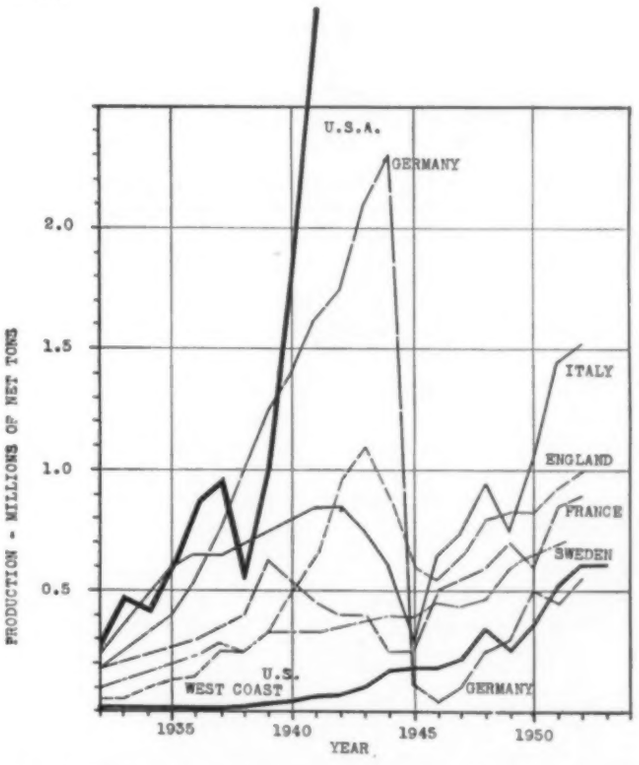


Figure 7 — Chart shows production of electric furnace steel in a number of countries. Data is furnished by British Iron and Steel Federation.

STEEL PRODUCTION

Figure 7 shows the production of electric steel in various countries for the period under study. Note that the electric steel production of the three west coast states has topped that of the last average figures from Germany and approaches that of Sweden.

Figure 8 shows the percentage of total steel production produced by the electric furnace in various countries. On this chart we have superimposed the percentage of electric furnace production in the three west coast states, and it is interesting to note how far, percentage-wise, the west coast is ahead of the United States, Germany, England and France.

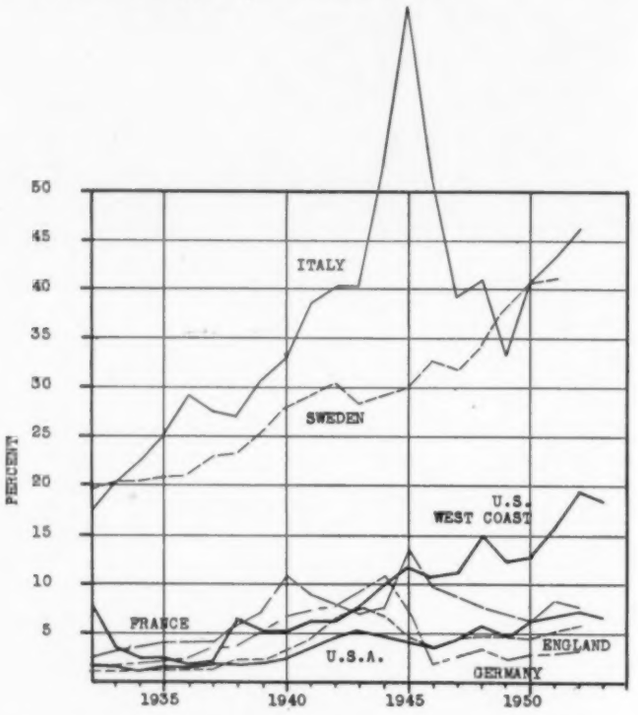
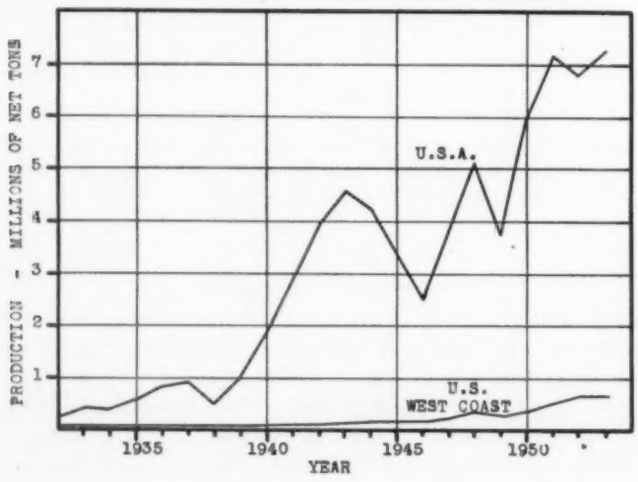


Figure 8 — Chart shows the percentage of total steel production produced by electric furnaces in various countries. Data is furnished by British Iron and Steel Federation.

Figure 9 shows the production of electric furnace steel in the United States. Tonnage-wise, in the whole economy, the west coast is producing 8.34 per cent of the electric furnace steel of the nation but percentage-wise the west is far ahead of the balance of the country.

Figure 10 shows the percent of total steel production produced by various types of furnaces in the United States. It is interesting to note that the electric furnace

Figure 9 — Chart shows production of electric furnace steel in the United States and on the West Coast.



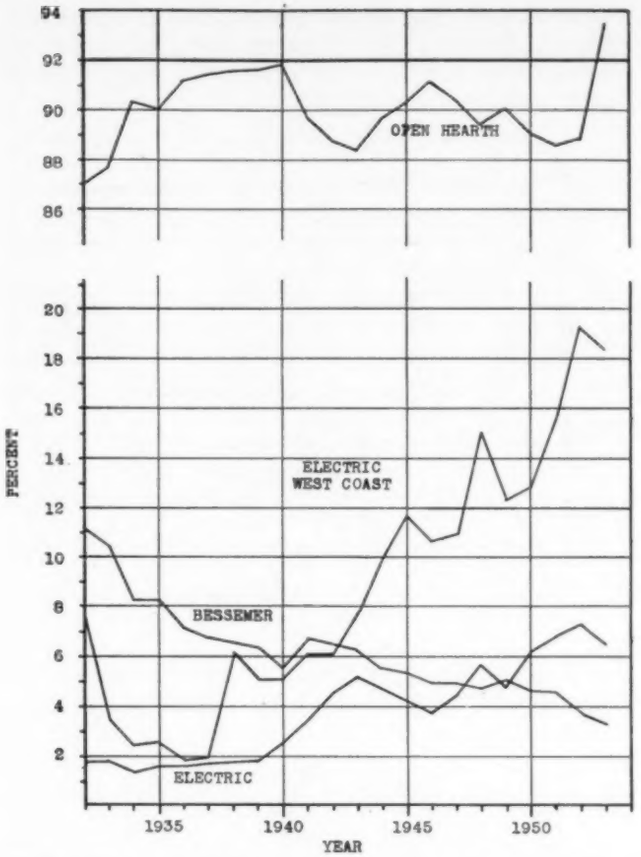


Figure 10 — Chart shows AISI statistics for per cent of total steel production produced by the various types of units in the United States.

has risen to seven and a fraction per cent of the total of the production in the country. However, from a capacity standpoint, according to the American Iron and Steel Institute, while the open hearth capacity of the country has increased from 1940 to 1953 by 39 per cent, in the same period, arc furnace capacity has increased 440 per cent.

WEST COAST STEEL PRODUCTION

In getting together the figures for this paper we were most fortunate in having most generous cooperation from the ingot producing plants in the three coastal states. This has enabled us to make up Figure 11. This figure has been limited purely to a study of steel production in the three coastal states from 1930 to date. The only point on the curve, that is at variance, is the 1930 capacity curve based on American Iron and Steel Institute figures, which, at that one point, includes capacity installed in the state of Utah. From 1934 on the capacity curve is based upon American Iron and Steel Institute figures for the three coastal states.

Below can be seen the total ingot and castings production curve which is a composite of the open hearth and electric furnace ingot production as reported by individual plants on the west coast plus figures from the Steel Founders' Society of America for their district No. 8 which includes, in addition to Oregon, Washington and California, the states of Idaho, Utah and Arizona. However, the maximum total steel casting tonnage

involved is only 3.5 per cent of the total and does not affect the overall curve too much.

The curve on open hearth production represents figures reported from the following steel plants; Bethlehem Steel Co., Seattle; Judson Steel Corp., San Francisco; United States Steel Corp. Pittsburg and Torrance plants; Bethlehem Steel Co., South San Francisco; Pacific States Steel Co., Niles; Bethlehem Steel Co., Los Angeles; Kaiser Steel Corp., Fontana. The curve on electric furnace production was based upon reports received from Northwest Steel Rolling Mills, Seattle; Isaacson Iron Works, Seattle; Oregon Steel Mills, Portland; Pacific States Steel Co., Niles; Bethlehem Steel Co., Los Angeles, and Southwest Rolling Mills, Los Angeles. Very full and complete figures were received from the foregoing which enabled us to set up the curve showing open hearth ingot production and electric furnace ingot production.

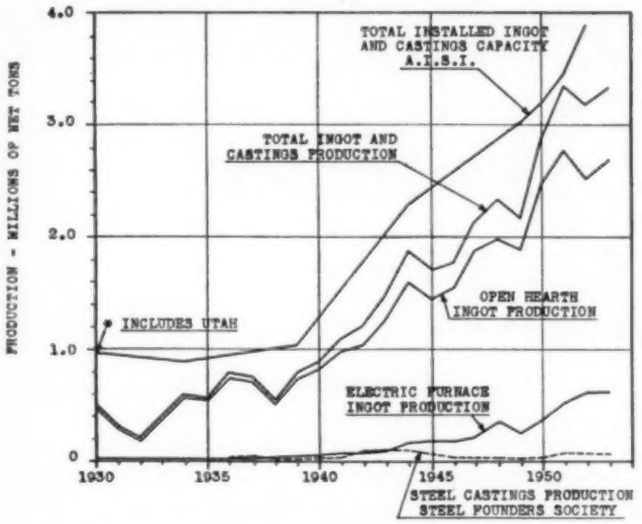


Figure 11 — Chart shows steel production in the West Coast states of Washington, Oregon and California.

We call your attention particularly to what has been happening on the West Coast in connection with the electric arc furnace. While open hearth production from 1930 through 1953 has increased 54 times, electric furnace production has increased 400 times. The American Iron and Steel Institute in its publicity figures showed, in averaging the 1952 figures, that, while the average of the country for the period 1940 to 1953 showed an increase of 44 per cent in that thirteen year period in steel ingot capacity, the western district, which, for the American Iron and Steel Institute, includes in addition to the three coastal states the state of Utah, has increased 223.1 per cent or five times the rate of progress over the balance of the nation.

In the light of what has been discussed in the foregoing, it is but logical that the West Coast should go ahead with the electric furnace as more than 50 per cent of its tonnage is made from cold scrap charges.

THE ELECTRIC FURNACE ON HOT METAL CHARGES

Up to this point, discussion has been limited to the electric furnace as applied to cold charge work. It has been the consensus of opinion that, in our economy of over 100,000,000 tons of ingot steel per year, the electric furnace could take no appreciable bite into that tonnage until someone had come up with a repetitive process using hot metal in the arc furnace.

Experiments have been going on in several plants during the past five or six years. These experiments have resulted in two developments. One in Canada is that a company is installing an oxygen, top-fired converter to blow hot metal preliminary to charging it into the electric furnace and, secondly, there has been developed in another plant, a repetitive practice in the use of 40 per cent hot metal charges. Heats of up to 50 per cent hot metal have been made but there just is not enough hot metal to go around all of the arc furnaces, and with the supply of hot metal available between the open hearth and electric, the hot metal level in the electric has been set at 40 per cent and in the open hearth at 50 per cent.

Experience had at this plant on hot metal shows that there is, as yet, no saving in power consumption; no saving in electrode consumption, but a 10 per cent increase in tons produced per hour. This repetitive practice has been in operation for less than a year, and it is felt that before this year is out there will be enough definite operating data and costs to give pause to those who have, up to now, while admitting the electric furnace was ahead of the open hearth on 100 per cent cold charges, could not take its position with the open hearth in handling hot metal.

TOP CHARGE OXYGEN CONVERTERS

It should be mentioned that another producer in this country is installing a blast furnace coupled with two top-fired oxygen converters for blowing down hot metal for introduction into their arc furnaces.

Question has been raised as to why, with a swing-aside roof furnace, it would not be possible to use the electric furnace crucible as the converter vessel; to swing the roof and superstructure to one side; run over the furnace a secondary cover equipped with fume off-take and oxygen jets; do the blowing in the furnace crucible; retract the auxiliary cover and swing the electrodes back on to finish the heat. It is known that in blowing with oxygen the boil rises to a volumetric figure of 7.5 to 1, and with modern top-charge, 20-ft diameter electrics, we already have in the lined crucible a volumetric capacity of slightly over 8 to 1 so that from the boil standpoint existing furnaces would handle the job.

It would, however, raise question as to wear on linings and the desirability of having the 20-ft shells easily removable and replaceable for reline as has long been the case in furnaces of 11-ft and 12-ft diameter.

THE PRESENT MARKET

For the first time in a good many years, operations have fallen below capacity. When the demand for steel turns downward, the demand for quality turns upward and quality, as put by Walter Mathesius, "is a competitive and ever changing standard."

This country has enjoyed a seller's market for a

longer period of time than has heretofore been had in our history, but there are those who remember when we did have a buyer's market. However, conditions have changed since that last buyer's market existed. In the interim there have been new methods of testing on steel products that have been introduced and customers in increasing numbers are broadening the application of these modern tests to steel furnished for their requirements. In a seller's market, they will "make do" with steel that does not quite meet with their requirements, but we are approaching a market where the buyer will insist on his specifications being met.

In steel production, this buyer's market is going to eliminate the diverted heat. In a seller's market, when a heat is not up to specification, there is usually some place that it can be put to fill other orders and that possibility will be continually narrowing.

Just what new specifications as to sulphur limits will be forthcoming remains to be seen, but the electric furnace, with its flexibility, is bound to have a special position in this buyer's market, which market is, after all, only a return to normalcy.

Furthermore, the electric furnace is one of the fastest methods known of producing a heat of steel and it is axiomatic in the steel industry that no man has produced a better heat by just working it longer. As Ralph Farley of Republic Steel puts it, "He must do the right work in the right way at the right time to finish the heat properly and get it out on time. That is why the faster heats so frequently produce the finer quality."

While the West Coast is outstanding in the United States in its development of electric furnace tonnage on cold metal practice, it is felt that the surface has been but scratched and, in the buyer's market ahead and with the development of repetitive practice on the use of hot metal in the arc furnace, new fields should be opened.

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ESTIMATING MOTOR ROOM INSTALLATION COSTS

. . . . there is no simple shortcut formula for making accurate motor room cost estimates . . . . the long, hard, detail method is best if reliable results are to be obtained . . . .

▲ IN considering the subject of motor room installation costs, the question immediately arises as to what constitutes a motor room. If the definition is restricted to the equipment housed within its walls, then in numerous instances, major associated drive units located outside the motor room, but powered from or through equipment installed therein, would be excluded. For example, this situation would apply to such installations as seamless pipe mills, bar or rod mills, temper mills, to some strip mills and to practically all strip processing lines. In each case the main drive motors for these major producing units are usually located outside the motor room, but are powered from or through equipment housed within its walls and are generally considered by steel men as a part of the motor room. It is the writer's belief that the term "motor room" is more symbolic than specific and that what is required is a discussion which would include all motor drives and related elements associated with a project whether housed within the motor room walls or outside. It is also assumed the subject would exclude the motor room building itself, as it is generally considered a structural item. It is on this definition that the contents of the paper will apply.

Probably readers will be most interested in some reasonably accurate method of estimating the dollar cost of motor room installations which could be applied before complete construction details have been developed. This is a very desirable objective, and if available, would fill a long-felt need in the industry. The writer regrets he is not prepared at this time to suggest any such formula suitable for general application, because steel mill motor rooms differ so widely in numerous essential factors that unit costs for any specific project are seldom if ever directly applicable to other installations without risk of substantial errors. The reasons for this situation will be discussed later.

At first glance it would seem there should be a reasonably definite relation between installation costs and some previously established value, such as the total cost of the electrical equipment or the total horsepower of the connected loads. Probably either one or both of these cost ratios, as determined from some previous installation, have been utilized by some of our members in making preliminary estimates for budget purposes or appropriation requests. Within limits, such unit costs are very useful for estimating a proposed installation provided it will be a reasonably close duplicate in all essential factors of the project with which it is compared.

Unfortunately for our present purpose, duplication to this degree or even a close approximation thereof, is seldom encountered to such extent that unit costs of the character indicated can be applied successfully to other installations without considerable modification. The near duplication would have to exist not only in the equipment costs or in the number and rating of the drives, but in other tangible and intangible factors, which are capable of exerting even a dominating influence on installation costs. Among these seldom duplicated but predominating factors will be found such items as design and type of mill, its end product, equipment layout, lubrication system, cooling and ventilation facilities, site conditions, scope of work, labor rates and material costs, tooling requirements, mill interferences, urgency of completion, weather conditions and other significant influences.

Evidence that factors other than cost of the electrical equipment or the connected load exert a predominant influence on installation costs is well illustrated in the experience with 36 motor rooms constructed within recent years by the company with which the writer is connected. These projects include blooming and slab mills, plate and bar mills, pipe and

tube mills, hot finish and cold rolled strip mills, temper mills and processing lines. The installation costs and the connected load for each of these projects are definitely known, but, unfortunately for the present purpose, equipment costs have thus far been established in only a few instances. The installation costs for individual projects ranged from less than $100,000 to more than $2,500,000 and the connected load for the 36 projects totalled 1,247,390 hp of electrical equipment. This includes drive motors and all associated electrical equipment expressed as horsepower.

When the total installation cost for these 36 projects is calibrated against the total hp of connected load, the average unit cost is $27.40 per hp. Attempts to combine selected projects of similar type and apparently having similar construction features, into two groups more closely related, disclosed average unit costs of $29.40 and $31.20 per hp, respectively. While these three average values were reasonably close, there were large differences among individual projects. For example, in the second group, they ranged from a low of $11.20 per hp to a high of $62.10 and in the third group from $9.31 to $94.50 per hp.

When installation costs were calibrated against total costs of the electrical equipment in the few instances where such figures were available to the writer, similar variations were disclosed although the range in unit ratios was not so great. However, the examples available for comparison were so few in number, they were not considered sufficient to develop conclusive results and for that reason are not included. However, this method justifies further investigation, and if the members of the AISE can furnish data on total costs of electrical equipment as compared to installation costs, it would be of considerable assistance in further consideration of the subject. These wide variations in unit costs should clearly indicate that from whatever source such figures are obtained, they should be used with discretion and not relied upon for any specific installation unless all applicable factors can be properly evaluated.

It should be thoroughly understood the preceding unit costs are not truly comparative for the reason the individual projects differ widely in respect to the predominating factors previously referred to, and are submitted here only as a rough guide as to what may be encountered in a specific job and as an indication of normal boundary limits. The figures are presented as actual construction costs and without attempting to adjust for unlike conditions, for if this were done, the results would necessarily involve estimates of more or less uncertainty and their usefulness in depicting the various factors which influence motor room installation costs would be materially lessened.

Motor room installations are not alone in their widely varying unit costs as public utility power plants exhibit a similar characteristic in the man-hours required to install turbo-generators with their plant auxiliary equipment, associated transformers, switchgear and other facilities. These installations present a far greater similarity in the power units involved, the plant layout and circuit requirements than would be found in an equal number of steel mill projects. Yet when calibrated in man hours per kw of turbo-generator capacity, this single item of labor, without even being translated into changing dollar values, will vary as much as 4 to 1 depending upon the scope of work and other dominating factors encountered for different installations.

Experience demonstrates that the most reliable estimates of installation costs are obtained when the project is broken down into as many detailed items as practical, and each item then estimated individually using current material and labor costs. By using this method, the miscalculations which inevitably occur tend to iron out in the total. As a preliminary to whatever method is used, however, it is essential that the applicable unit costs, the physical conditions at the site, the scope of work and other controlling factors be established as accurately as possible for the job under consideration, else the figures may be very misleading. Even when all reasonable care has been exercised in assembling data and in making the calculations, job conditions may change to such an extent prior to and during the execution of the work, that the final results are seriously affected.

It may be of interest to outline some of the variable factors which make it impractical to establish reliable unit costs for estimating motor room installations. One important source of variations lies in the physical conditions at the site, i.e. whether it is virgin territory or has been previously occupied. If not previously used for heavy industrial purposes, the cost of site preparation will normally be of minor expense. On the other hand, if the site has been used previously for mill purposes, its preparation may involve the dismantling, relocation or removal of equipment, the repair or alteration of old buildings, construction of basement or pit under hampering conditions, the blasting out of old foundations, the rerouting or replacement of deeply buried sewers and pipe lines or other expensive operations, all of which sometimes appear as motor room installation costs. Furthermore, if the site is not readily accessible to heavy duty construction equipment, then slower and more costly methods must be used not only to remove obstructions, but also to prosecute the construction work. If production equipment on the site must be continued in operation during construction work, then extra costs are frequently incurred in providing temporary construction or in relocating auxiliary facilities.

Unit costs for excavation and concrete work can, and generally do, differ materially at different locations, while unknown or unexpected under surface soil conditions such as rock, water or sand may result in extra expense for blasting, pumping or shoring. Location of the disposal area for excavated material, excessive width of working space around the form sometimes demanded by the workmen, the use of sheet piling if found necessary to protect adjoining structures and other physical conditions of similar nature, all of which influence costs, may exist to a greater extent at one motor room location as compared to another.

Even the price of a staple commodity such as ready mixed concrete may differ as much as 30 per cent in one locality as compared to another. Other differences in foundation costs may be found in oversize base di-

mensions, the weight and disposition of reinforcing steel, the amount and type of piling required, the necessity of using quick setting cement, thickness of grout and other features of a similar nature. Foundations in the motor room are sometimes extended to accommodate gear drives or other mechanical equipment, and installation costs may even include erection of these parts in some projects.

The design and type of the mill and the arrangement or type of accessory units necessary for its end product, which in turn are reflected in the electrical equipment required for operation, will materially influence installation costs because of the greater or less capacity in power units, the number, type or location of control devices or operators' desks and the wiring involved. Also the extent and character of the lubrication systems, location of pumps, motor, control devices and storage facilities differ materially for mills even of the same type. A similar situation exists with respect to type of cooling and ventilating systems whose installation costs may be affected materially by the source of utilities such as air, steam or water, and location of sewer connections, and whether or not structural changes are necessary for their installation or successful operation. In each of these elements, as elsewhere throughout the mill, the degree of economy in design and layout will have a substantial influence on the installation costs.

Facilities for handling and storing motor room materials and equipment may even introduce unexpected differences in cost. Storage space either remote from or too close to the work area can consume an excessive number of manhours. In one large installation it was found necessary to store wiring materials, switchgear and control equipment in the motor room. The resulting congestion not only interfered with the progress of the work, but necessitated frequent shifting of many items. This combination increased the manhours required for the actual installation work over 30 per cent. The presence or absence of adequate equipment handling facilities likewise affects comparative construction costs. At a recent large motor installation there was neither railroad siding, truck entrance or overhead crane in the motor room, thus making it necessary to use jacks, rollers and winches to transport and place the motor on its foundation. As a result the manhours expended for handling the equipment were four times what would have been required had adequate facilities been available.

Motor rooms are sometimes constructed with an individual transformer station located outdoors but in close proximity to the buildings. If supplying no other load, the substation with its indoor secondary switchgear and feeders may properly be considered a part of the motor room installation under the definition previously suggested. In that event the installation costs for a motor room of this type would exceed those for one of like construction but which received its power from a plant distribution system where charges for its power supply would be represented by the minor cost of connecting incoming feeders only.

Other common differences affecting the comparative costs of motor room installations will be found in such features as the rated capacity of the equipment, the system voltage and type of construction for motor leads and feeders. It is obvious that the difference in installation cost for large equipment as compared to a duplicate of half its capacity will not be in proportion to their hp ratings. Likewise, the cable circuits for a low voltage system will cost substantially more to install than like circuits of the same capacity, but operating at voltages three or four times higher. Heavy circuits installed in the open or on cable trays or on racks in ventilating tunnels, will cost materially less for the same current carrying capacity than if underground or embedded conduit runs are necessary. Other important elements in the electrical work which can show considerable disparity in installation costs exist in the relative proximity of motor room equipment to its associated mill drives, the presence or absence of a basement, the relative complexity of control systems, and the type or location of air cleaning and ventilating equipment.

The discussion thus far has referred to the influence which the physical factors of the project exert on installation costs. However, there are other factors of a less tangible nature which exert an equal, or at times an even greater influence. Among such intangibles, consideration should be given to the effect of co-ordination between the several working groups, quality of supervision and engineering services, prevailing labor rates and work efficiency, urgency or completion and weather conditions. It is sometimes difficult to evaluate the effect of these forces properly, but they influence the cost of every construction project in greater or lesser degree and are frequently a major reason why motor room installation costs vary over such a wide range.

In any construction project requiring the services of different work groups, it is almost inevitable that conflicting activities will develop as the job progresses. If permitted to reach a climax, these conflicts can readily result in the loss of many costly manhours while differences are being ironed out and in extreme cases it may even become necessary to tear out and rebuild. Many of these conflicts can be avoided by properly co-ordinating the efforts of the various work forces through careful day by day planning. Labor costs can readily move into high gear unless the conflicting interests of the different forces on a job can be channeled into a cooperative effort.

Job supervision extending from headquarters down through the various levels to the individual work units can materially influence labor costs depending upon its success in developing a cooperative spirit among the workmen and its effectiveness in transmitting plans and information to them. Qualified field engineering service capable of interpreting intricate drawings into readily understood sketches or instructions, can avoid many wasted manhours by otherwise skillful workmen attempting to understand unfamiliar drawings by their unaided effort.

Labor costs and labor efficiency are two vitally important factors entering into any comparison of motor room costs because the labor item may account to as much as 40 to 50 per cent of the direct installation

cost. It is well known that labor costs have advanced year by year until today in some trades they are as much as 50 per cent higher than they were six years ago. Furthermore, uniformity in hourly rates does not exist in all steel mill districts. From the foregoing it should be evident that comparative motor room costs will be materially affected by both the labor contract period and location of the project.

When urgency of completing a project within rigid time limits enters the situation to such an extent that work must be prosecuted on a premium time basis, then all labor costs advance at a more rapid rate than the accomplished work. In extreme cases, the labor costs may increase as much as 37½ per cent during the urgency period while at the same time labor efficiency may suffer a corresponding reduction during extended periods of premium time work. Extreme weather conditions will likewise reduce labor efficiency, particularly where the men are exposed to low temperatures, or excessive rainfall. Motor rooms constructed under the conditions outlined will naturally show higher relative costs than others where work conditions are more favorable.

While these comments have not covered the full range of variable cost items which appear in different motor room installations, they will possibly be sufficient to indicate there is no simple shortcut formula for making such estimates where a reasonable degree of accuracy is required. The writer believes the long, hard, detail way is the best way if the most reliable results are to be obtained.

If the approximate methods frequently used for estimating motor room installation costs are not considered sufficiently accurate for application on some new or unusual project, or if competent personnel is not readily available to work up the more laborious detail method, then the services of some qualified organization experienced in the widely varying nature of industrial installation work could be utilized. From its accumulated cost data combined with its experience gained with projects of many different types, such an organization should be able to furnish within a relatively short time, cost estimates with a degree of accuracy sufficient for normal budgetary purposes. When making such an assignment, it should be necessary only to outline the predominant features of the proposed installations, establish the scope of work involved, and provide opportunity for the estimator to view the site and become familiar with local conditions affecting the work. This procedure is frequently followed and has proven well worth the relative minor expense involved. No commitment relative to further work in connection with the project need be implied by an assignment of this character.

DISCUSSION

PRESENTED BY

F. O. SCHNURE, Electrical Superintendent, Bethlehem Steel Co., Sparrows Point, Baltimore, Md.

C. W. CRISTAL, Vice President, Construction Sales, Dingle-Clark Co., Cleveland, Ohio.

F. O. Schnure: Mr. Dudley's paper has clearly shown the reasons why there can be no empirical formula for estimating electrical installation costs by relating them to a dollar value per horsepower. The paper at once rightly comes to the conclusion that the physical limits of the motor room rarely cover but a portion of the scope of the work. From this point on it is shown that close duplication of previous jobs rarely exists, and that the varying factors of site location, the scope of the work covered by electrical installation, the cost of materials delivered to the site, the facilities for handling same, electrical system voltages and labor cost and efficiency, are all important considerations that point to a detailed study in order to achieve an estimate.

It follows then, to use the authors words, "the most reliable estimates of installation costs are obtained when the project is broken down into as many detail items as practical and each item estimated individually."

As a final check, the experience gained on previous jobs can be used after bringing up-to-date the factors involving material, equipment and labor cost.

C. W. Cristal: I would like to emphasize what Mr. Dudley has said about the differences in various steel mill jobs, and also to further emphasize that there is no substitute for a detailed take-off and estimate. Such an estimate is time-consuming. It requires a great deal of detail and it is necessary to assemble enough information to make at least a theoretical layout. All of this is very expensive, but in our experience it is the only sound approach to an intelligent price.

We must be realistic, and many engineers have to have fast budget figures for appropriation purposes. Unfortunately down through the years, budget figures have caused much difficulty because whenever a figure is made, regardless of the detail with which it was prepared, it has a way of becoming the price. It is something that you live with, and these prices have often been the source of much difficulty.

In our experience, there is no easy shortcut, but we have found that comparing one job with a similar job that we have executed or estimated in detail, does produce a reasonably satisfactory budget price, providing it is done on an intelligent basis.

In other words, useful data for future estimating may be obtained if a breakdown of costs has been carefully kept, separating the material and labor for a particular mill proper from the auxiliary facilities such as lighting, the main a-c high voltage power feeder, substations, d-c mill supply generation and rectification, low voltage d-c and a-c power feeders and tie lines, crane facilities, auxiliary shops such as roll shops, machine shops and the like. A budget estimate of reasonable quality can then be established by carefully comparing the requirements of the various component parts of the proposed mill with those equivalent parts of a former mill installation giving of course, due consideration to material and labor price levels.

as well as the labor supply and its effect on productive efficiency. We have been quite successful in preparing a budget estimate by this comparative method.

Great care must be used in establishing the scope of the work. Frequently, budgets are made and then many months later after material changes in the scope of the work, the budget is not revised and it should be. We have found that failure to properly analyze the fringe requirements of a mill such as the various feeders and substations before mentioned, frequently causes greater budget error than the analysis of the requirements of the mill proper.

Our Company maintains very accurate records kept in hours, for labor, and in dollars, for material, and these are continually checked with the actual results. This is the manner in which we arrive at our estimating units.

For contract purposes, we know of no other method than to make a take-off from either drawings which have been prepared, or a theoretical layout, which is made up prior to making the take-off.

Wray Dudley: It is comforting to learn that other men of broad experience in estimating motor room installation costs have encountered similar difficulties in this effort. If further evidence of this condition is desired, it is only necessary to examine contract bids for motor rooms or in fact any large project, which are submitted under identical specifications. Even though each bidder prepares his estimates from the same information and presumably endeavors to make a bid which will permit only a reasonable margin of profit, the prices will frequently differ materially, and from low to high the range may be as great as 25 per cent or even more.

The differences may be due to various influences such as errors of ommission or commission, a determined effort to obtain an award at any price, the expectation of recovering probable losses by economizing on the job, a more efficient organization, more conservative standards of construction or higher grade workmanship. Regardless of the cause, the fact remains that even those whose livelihood depends upon the making of accurate and conservative estimates will arrive at different figures for the same project.

The uncertainties concerning installation costs referred to in these comments need cause no surprise nor loss of confidence. They are the common experience of mankind in every branch of human activity, and have existed from time immemorial. In other days the situation was summed up in the phrase "caveat emptor" or "buyer beware," and this same admonition is as pertinent today as when first spoken. In estimating motor room installation costs, therefore, it would be the part of wisdom to utilize the best judgement available and then be prepared for any reasonable variations which may occur as the project develops into its final form.

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SEPTEMBER 28, 29, 30 . . . OCTOBER 1

APPLICATION OF BRONZE BEARING ALLOYS

By JAMES L. DUCHENE
National Bearing Division
American Brake Shoe Co.
Pittsburgh, Pa.

. . . . selection of bearing material must be related to design and maintenance . . . .

▲ THE proper application of any bronze as a bearing material may be likened unto a triangle with the three sides being design, material, and maintenance. With all of these factors at a high point, service life and trouble free operation are in direct proportion to the large area enclosed. When any of the sides or factors are shortened, a smaller area triangle is formed with a corresponding decrease in service life.

It is not our intention to discuss all three of these factors in detail, but rather to concentrate on the material side of the triangle. Maintenance problems such as regular inspection, proper lubrication, operating data can best be handled by the master mechanics, or maintenance people, while design problems should logically be discussed with mill, engine, and machine builders and their engineering staffs. Naturally, people concerned with the material side of the triangle should serve the industry in a liason capacity and try to coordinate actual application tests and data with the theory of laboratory tests to promote easier maintenance and better design. Better scale guards, oil seals, housings, and bearings have resulted from this cooperation.

It does not take long association with the bearing industry to realize that each bearing problem, because of the many factors involved, seems to be different and that it is impossible to look at a table or a book and arrive at a satisfactory answer. In selecting a bearing material one must bear in mind the relation between the bearing and the reciprocal moving part. Invariably the moving part is the one to be protected and the wearing of the bearing is to be preferred to the wearing of the shaft.

A bearing material, to perform satisfactorily, must have certain definite characteristics. In the past, materials were judged mainly for their tensile strength, yield strength, elongation, and hardness. However, recent studies by oil companies, steel mills, machinery builders and bearing suppliers indicate that there are now additional factors to be considered such as:

1. Fatigue strength.
2. Embeddability.
3. Conformability.
4. Seizure resistance.
5. Corrosion resistance.
6. Method of manufacture.

Selection of the proper bearing material is in a sense a compromise, because no one bearing material will satisfy all of these factors, so depending upon which of these factors is deemed the most important, different people might select different alloys for the same installation.

1. *Fatigue Strength* is the maximum stress that a metal will withstand without failure for a specified number of cycles of stress. Fatigue strength in a bearing should be high so that failure will not result from overstress of the bearing from impact and distortion. When a bearing does fail in fatigue, it is usually at a point of stress much lower than the ultimate strength of the material. Fatigue failure may be a combination of the interruption of lubrication locally, and cycles of heating and cooling, setting up excessive tensile stress. Either or both of these cause cracks which may result in a spalling condition. Bronze with a relative better thermal conductivity than other bearing materials can dissipate the heat of the localized hot spot over the entire surface of the bearing.

2. *Embeddability* is ability of a bearing material to enclose or surround foreign material in a bearing. The need for embeddability varies greatly depending on the application, but it is particularly important in steel mill applications because of mill dirt and steel scale. A soft material can embed dirt and thus avoid hot spots. Babbitt bearings have excellent embeddability and the use of bronze bearings with babbitt pockets enables you to keep the high bearing strength of bronze without losing the embeddability. Simply stated, embeddability in a material is one that has high plastic deformation.

3. *Conformability* is the ability of a bearing material to be resilient to shaft or journal deflections. It allows a bearing to deform elastically under moderate impact loads, thereby cushioning the shock which permits grit to pass through a bearing without excessive scouring of the journal or bearing rather than embedding the particle. Conformability depends primarily upon the accuracy of manufacture of the machine or unit in which a bearing is used, and definite limits could

be set if more information were available on shaft deflection and operating characteristics. Conformability in a bearing is helped if the material has a comparatively low elastic modulus of say 10,000,000 psi. This permits the material to yield to shaft deflection and prevents seizure.

4. *Seizure Resistance* can best be described as the ability of a bearing material to avoid grasping, snatching, or holding to irregular surfaces on the journal. This is very important when there is a lubrication failure of any extent and there is metal to metal contact. When the journal and bearing are no longer separated by an oil film you must depend upon the low friction property of the bearing. This is the main reason why copper, tin, lead alloys are to be preferred as bearing material.

5. *Corrosion Resistance* in a bearing material is the ability of a particular material to resist the eating away or gradual diminishing of a bearing by chemical action. Some lubricating oils when heated to temperatures above 250 F, oxidize and become acid in nature. In leaded copper, tin alloys in particular, the lead is corroded away because it is in mechanical suspension and voids or blank spots result. Fatigue aids corrosion and cracking is accelerated. Also of prime importance in steel mill application is the use of water sprays during rolling operations. Some mill water is high in acid or lime content which has been used to neutralize the acid condition and corrosion resistance must be high to resist these damaging chemicals.

6. *Method of Manufacture*—Is the bearing made as a sand casting or by some improved method such as centrifugal, permanent, or shell molding? There are many metallurgical reasons for centrifugal castings over sand castings that do not show on property tables or impact charts. The main advantage of centrifugal cast alloys is the fact that there is solidification from one direction only because the metal is cast against a spinning surface. This does away with known middle wall weakness of sand cast material where the material solidifies from each surface toward the center of the wall. Interference of dendritic solidification and internal shrinkage often cause sand cast material to be hydraulically unsound, when the inner and outer surfaces are removed during the machining of the bearing. When castings are made in a permanent chill mold or a shell mold backed by steel shot, it is possible to make castings of great accuracy. Because of this accuracy they may be installed with little or no machining and there is the opportunity to use the finer grained material on the outside of the casting. This same material would normally be removed from a rough sand casting during the machining operation. Castings must be made properly to insure a bearing or group of bearings that will give uniform performance. If the casting is not gated properly, the gate may freeze off with a resultant shrink or void in the casting. If casting temperatures are not controlled, it may effect different properties between the first and last castings of a lot. Those familiar with foundry principles and metallurgy of the alloys will realize that sloppy foundry practice can account for more variations in properties of a casting than missing the chemical analysis by a point or two. If a good casting is obtained, it is possible by improper machining to work harden the surface, or to sweat out the lead. By emphasizing these lesser known qualities of bearing materials, it is not intended to overlook the properties of strength and hardness. When the bearing properties of a material are good, the load capacity of a bearing is largely determined by the strength of the material. When the load is steady, only compressive strength or resistance to squashing out is required. When loads are applied intermittently, the tensile and yield strength become important. Mechanical or compressive strength should be high, but it is not as important as some people think. Soft bearing materials or alloys often stand up very well under extreme rolling mill pressures because they are mechanically strong at temperatures a safe margin above maximum operating temperature. Demands for strength are in opposition to demands for good frictional properties, but most of the better grades of bronze bearing alloys have adequate strength for most operations.

Now, let us consider some of the alloys.

Early bearing materials were generally alloys of copper and tin and were called bronzes. The copper tin matrix later included lead in suspension and at present this basically sound alloy is still in use with other elements now being added such as zinc and nickel to give specific properties. The term bronze generally refers to copper-tin mixtures in contrast to copper-zinc mixtures which are called brasses. Some notable exceptions to this generalization are aluminum, manganese, and silicon bronzes which will be mentioned later. Bronzes are generally preferred as a bearing material because multiple growth of crystals form in this alloy in contrast to single crystal growth of a copper-zinc alloy. The brass is a hard mass and the bronze is a group of hard and soft spots which allow space for minute oil reservoirs. Brass is a rough, harsh metal in contrast to the smooth soft surface of bronze.

The premier position held for many years by bronze bearing materials has now been invaded by non-metallic resinous bearings, needle bearings, ball and roller bearings. This invasion has been due largely to the complaisance and technical ignorance of many of the bronze foundries. A thousand and one alloys have been developed each apparently to suit a given condition. These in the main are nothing more or less than variations of the basic alloys and it is very hard to decide which of them are bonafide. In general there are six alloy groups that will give a range in physicals from the soft to the very hard bronzes.

Typical of the first alloy group is SAE 64 shown in Figure 1. In steel plants this composition is the most widely used, and when amounts of phosphorous in excess of 0.25 per cent are added, the hardness increases rapidly. In this state, the metal has a tendency to be open in structure which is not undesirable because of the microscopic amount of lubrication that can be absorbed. If a small amount of nickel is added, up to 1 per cent, this alloy becomes fiberous in nature and has good resistance to impact. With this open fiberous structure, it is possible to hold lubricants in mill bearings when the necks are flooded with water. When loading limitations will not permit use of high lead

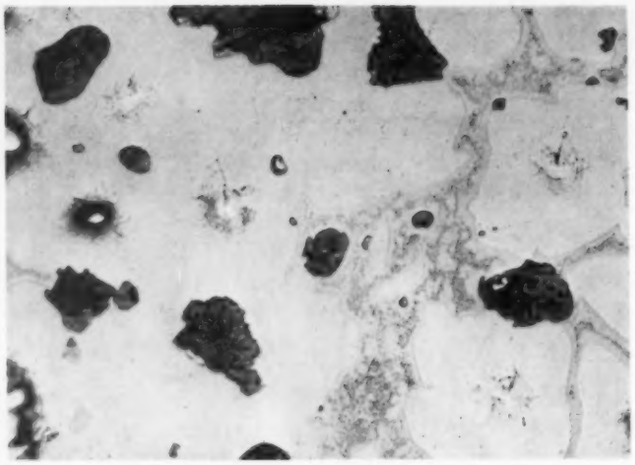
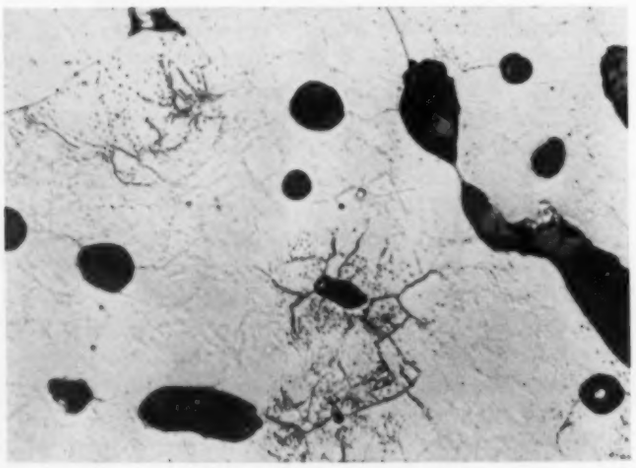


Figure 1 — SAE 64 phosphorus bronze contains 80 per cent copper, 10 per cent tin and 10 per cent lead. Properties are 32,000 psi tensile, 17,000 psi yield, 10 to 15 per cent elongation in 2 in., 14,500 psi deformation and 65 BHN. (Magnification about 470X)

Figure 2 — SAE 62 gun bronze contains 88 per cent copper, 8 to 10 per cent tin and 2 to 4 per cent zinc. Properties are 30,000 psi tensile, 18,000 psi yield, 14 to 20 per cent elongation in 2 in., 15,000 psi deformation and 65 BHN. (Magnification about 470X)

Figure 3 — SAE 67 high lead bronze contains 78 per cent copper, 6 per cent tin and 16 per cent lead. Properties are 25,000 psi tensile, 14,000 psi yield, 12 to 17 per cent elongation in 2 in., 12,000 psi deformation and 60 BHN. (Magnification about 470X)



bronze, 80-10-10 must be used even though lubrication failure would cause undue wear on a soft shaft or journal. This material is better than average in conformability.

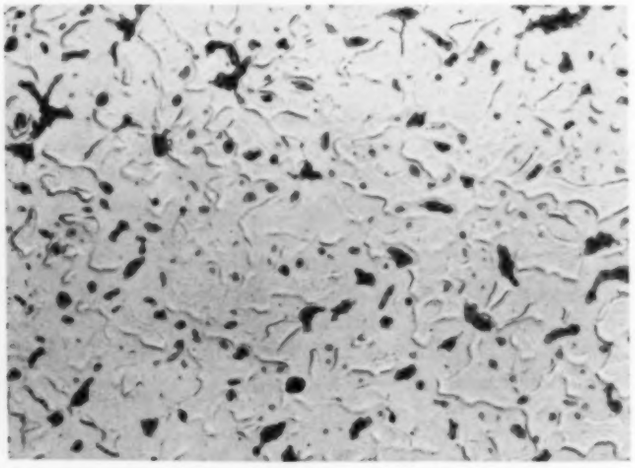
Typical of the second group of alloys is SAE 62 shown in Figure 2. This alloy is the basic copper tin matrix with 2-4 per cent zinc being added as a dioxidizing agent to produce a close dense structure for this metal. Basically, this alloy is a structural metal and can be used to advantage to produce a dense casting that is hydraulically sound. Bearings designed with thin wall or irregular flanges lend themselves to manufacture from this alloy. In no case should this alloy be used unless there is adequate lubrication provided.

Figure 3 shows an alloy that is typical of the third group, SAE 67. Leaded bronzes include a wide range of copper tin matrixes with lead in mechanical suspension within this matrix. The amount of lead varies from 6-24 per cent depending upon the severity of the application, the amount of embeddability needed, and whether emergency lubrication is a factor. When lubrication ceases, bearing temperatures rise and as long as this temperature is not excessive, the spheroids of lead will smear over the surface. When the temperature rises above 620 F, the lead will melt and sweat out and takes the place for the time being of the lubricant. This alloy is less expensive than SAE 64 and unless there is severe loading or an end thrust condition, it is to be preferred because of the emergency self lubrication properties. This material is also very easy to machine with cutting speeds up to 3,000 fpm not being uncommon. This alloy can be cast centrifugally if casting machine speed is closely controlled. Bushings made by this method from this alloy are in wide use in the diesel engine field. This material can be used where it is impossible to harden the journal and emergency quality of lead sweat will prevent galling and seizing.

Typical of the sand cast properties and structure of an unheat treated aluminum bronze are shown on Figure 5.

Aluminum bronzes are a very versatile group of alloys. By changing the composition, the mechanical properties can vary from that of a strong alloy with high ductility to a very high strength alloy in the range

Figure 4 — Photomicrograph shows centrifugally cast lead bronze magnified at about 470X.



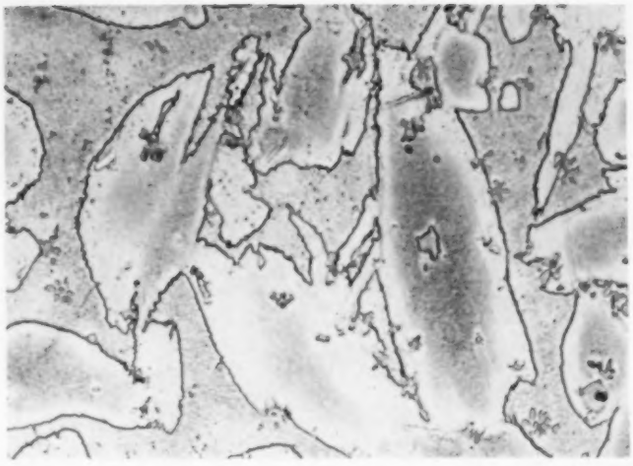
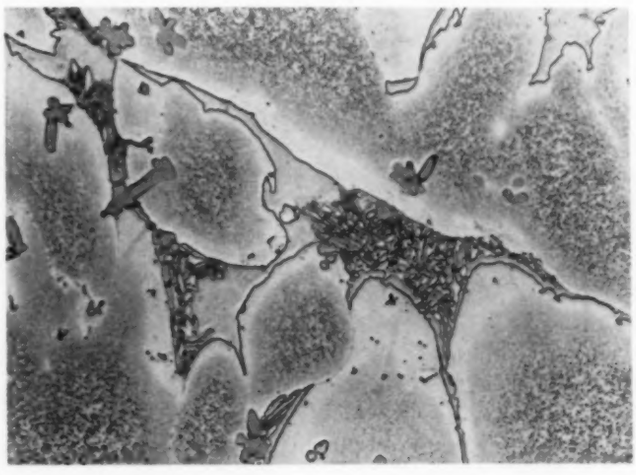


Figure 5 — SAE 68 as-cast aluminum bronze contains 89 per cent copper, 10 per cent aluminum and 1 per cent iron. Properties are 70,000 psi tensile, 25,000 psi yield, 20 per cent elongation in 2 in., 22,000 psi deformation and 130 BHN. (Magnification about 470X)

of 100,000 psi tensile strength. Primarily, there are two types of aluminum bronze, the single phase and double phase or duplex alloys. Since 8.4 per cent aluminum is soluble in copper and when this amount is exceeded the duplex phase of this alloy is entered. Single phase aluminum bronzes are much like copper tin alloys in that they cannot be heat treated. The duplex form of this alloy responds to heat treatment in much the same manner as steel. Iron is added in the range of ½ to 5 per cent to increase the strength and to assist in refining the grain structure.

This alloy is now coming into greater use as a so-called bearing material with machines carrying greater loads and producing more tons of product. A well known variation of this alloy is one composed of 80 copper, 10 aluminum, 5 iron, and 5 nickel with 90,000 psi tensile, 60,000 psi yield and 200 BHN not being uncommon in the unheat treated state. Aluminum bronze, because of the formation of a thin oxide film on the surface, is resistant to oxidation and scaling at elevated temperature. Above 600-750 F, however, this alloy will lose its high strength and shock resistant quality. This material can best be used in heavy duty

Figure 6 — Photomicrograph shows SAE 68 heat treated aluminum bronze magnified at about 470X.



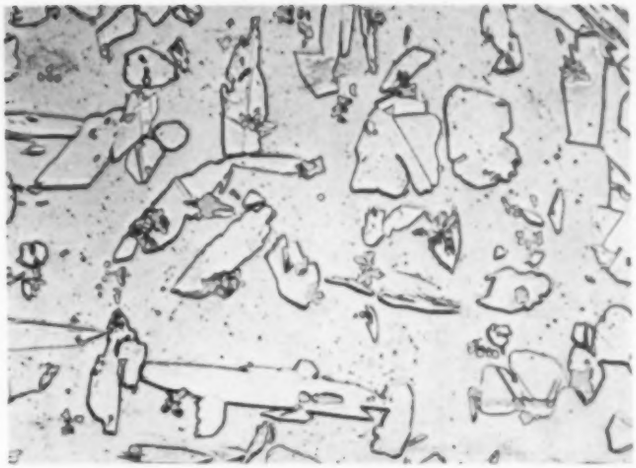


Figure 7 — SAE 43 high strength manganese bronze contains 64 per cent copper, 5 per cent aluminum, 3 per cent iron, 25 per cent zinc, and 3 per cent manganese. Properties are 110,000 psi tensile, 55,000 psi yield, 10 to 20 per cent elongation in 2 in., 60,000 psi deformation and 200 BHN. (Magnification about 470X)

slow moving loads and is not to be used for high speed application.

Typical of the fifth group is SAE 43, physicals for which are shown in Figure 7. This material is best termed a high strength yellow brass because it is basically copper and zinc with small amounts of aluminum, manganese and iron added. One of the reasons for this high strength is because it is a high shrinkage metal. If you close your fist, you consolidate the muscular power of the arm and hand the same as high shrinkage consolidates the crystal structure within a metal. This alloy is used for trunnion bearings on lift bridges, bessemer convertors, and for screw down nuts where high physicials are needed. Comparable physical properties to heat treated aluminum bronze are available in the as-cast state without the extra cost of heat treating. Unless these high physicals are absolutely necessary, a better bearing material is to be preferred because this dry, harsh bronze must have the best lubrication possible or heating will result. This alloy is also best used for heavy duty slow moving loads.

Figure 8 — A typical silicon bronze contains 95 per cent copper, 4 per cent silicon and 1 per cent manganese. Properties are 48,000 psi tensile, 18,000 psi yield, 20 per cent elongation in 2 in., 18,500 psi deformation and 90 BHN. (Magnification about 470X)

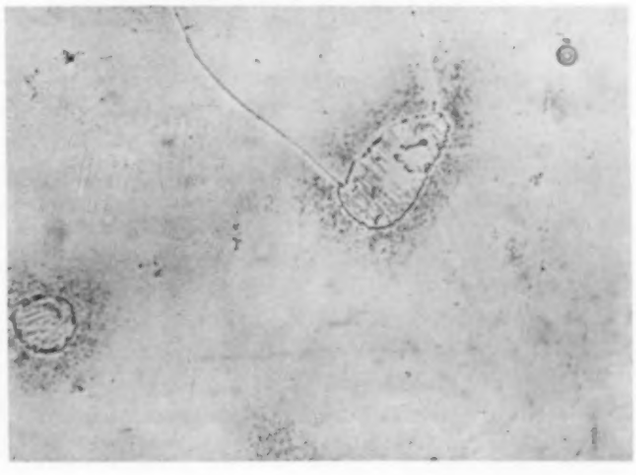


Figure 8 shows the physical and chemical properties of a typical silicon bronze. Silicon bronzes all have a composition of copper and silicon and a third or fourth alloying element of iron, manganese, zinc or tin. Increasing use of silicon bronze in many important industries, and superiority in many applications over tin bronze together with the high price at present for tin has lead to a more complete understanding of its engineering qualities. Recent bearing score tests seem to indicate that silicon bronze is at least as good as, if not better than, phosphorous and gun bronze, but not equal to leaded bronze. Silicon bronze that does not contain zinc has good corrosion resistance and maintains adequate strength. The biggest use of this material in steel mills is as a gear metal, and it has provided competition for the better known gear metal, SAE 65, which is an 89 per cent copper, 11 per cent tin alloy.

No mention has been made of the nickel bronzes because in general they are the basic alloy groups with nickel added. Nickel will improve the mechanical properties and grain size of most bronzes. In an effort to prove that proper application can lead to increased service life, it might be well to review some actual applications.

Figure 9 shows a bearing that was installed new on the top roll neck of a blooming mill. This bearing replaced a steel back babbitt bearing with bronze inserts and showed a bearing cost per ton of steel rolled of $0.00029. Service life of the bearing was increased from 13 weeks to 16 months and four days. This bronze bearing has two babbitt pockets which are solid when new, but as the bearing wears in the crown to a point where the section is thin, they gradually become a ribbed pocket. When the bearing is worn to a thin section the added strength provided by the ribs is needed. In addition, the embeddability of the remaining babbitt is required.

When this bearing is new, there is enough strength in the pad or heel to permit a full babbitt pocket. The location of these pockets is very important in that the normal operation load area has to be localized in relation to the center line of the bearing. By observing worn bearings one can notice that this load area always falls within a certain arc of the bearing. When this relative position has been determined, the babbitt pockets are located on the fringe of this load area. If the babbitt pockets are located within the load area, the bearing will eventually crack through this weakened section.

There are four lubrication holes on the end of this bearing. The two holes closest to the split line provide flood lubrication through grease grooves in the inside diameter or the bore of the bearing. The holes at the bottom of the bearing are drilled through the bearing, parallel to the center line of the roll neck to the collar or thrust face. It is important that these holes are drilled through the thickest section of the bearing so that there is no potential weakness caused by providing adequate lubrication.

This bearing is an outstanding example of the proper application of 8-10-10, and by providing high lead babbitt pockets in the proper place, this alloy's strength is retained in addition to the high embeddability of lead babbitt.

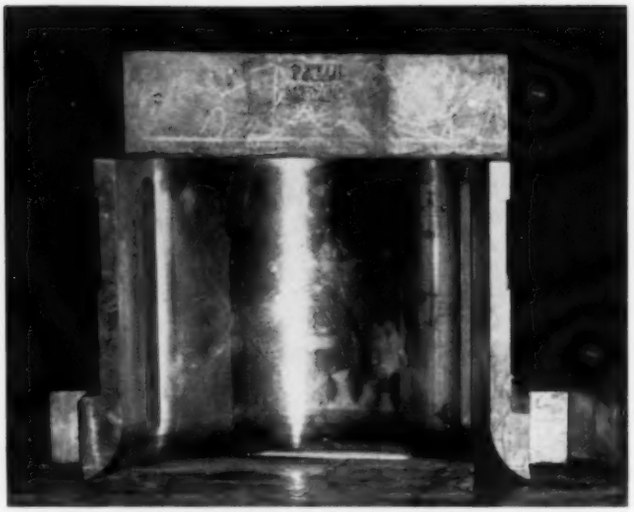


Figure 9 — Roll neck bearing for blooming mills shown replaced steel babbitt bearing and increased life very markedly.

APPLICATION OF BRONZE TO THREADED BEARINGS OR SCREW DOWN NUTS

When selecting the proper alloy for this type of application, the following factors are of prime importance:

1. Contact speed of screw in fpm.
2. Respective coarseness or fineness of thread.
3. Hardness of screw.

Figure 10 shows a small housing nut that has fine thread and is operated at moderately high speeds against a hard thread. A 3 per cent nickel bronze is shown here.

If the housing nuts are large such as those shown in Figure 11, and are used with a large screw, with coarse thread of high hardness, and there is slow speed, one may use manganese bronze or SAE 43. In addition to reviewing some basic application of standard bronzes to conventional design bearings, it seems important to note some new developments with these materials as well as changes in design and method of manufacture.

Figure 12 shows a bottom roll bearing for a 35-in. blooming mill. This bearing weighs about 1400 lb with a 20-in. bore, 20-in. length and is 28-in. wide. This bearing replaced a steel back babbitt bearing and special features include integral cast adjustment yokes and scale cover mounting brackets. Location of the babbitt pockets and lubrication was also very important in this bearing because of the severity of the application.

Figure 13 shows two cast-to-size bearings that are now being manufactured by various methods, the better known being:

1. Washed sand mold.
2. Croning "C" process, or phenolic resin shell.

Typical tolerances are as follows:

1. Outside diameter, 5.255 plus zero, minus 0.005 in.
2. Inside diameter, 4.5 plus 0.005, minus zero in.
3. Length, 6.755 plus 0.000, minus 0.005 in.
4. Width, 6.255 plus, 0.000, minus 0.005 in.

In shell molding, a metal pattern is heated in an oven

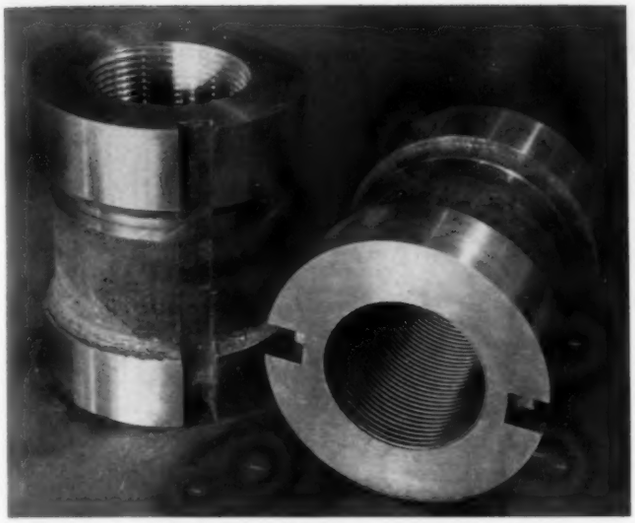


Figure 10 — A 3 per cent nickel bronze is suitable for small housing nuts with fine threads operating at moderately high speeds against a hard thread.

and then coated with a parting compound. The pattern is covered with a thin layer of fine sand mixed with a thermoplastic resin. The pattern and the sand resin shell are then baked in an oven. After a set time the cured shell is stripped from the pattern. A duplicate shell for the other half of the mold is made in the same way. The two shells are clamped together and put in a box for pouring. The shells are then backed with steel shot to prevent shells from breaking and to transfer heat from the casting so that you achieve a chilled surface effect.

The bearings shown in Figure 13 are ready for installation and permit use of the tough skin which is characteristic of most castings. This skin is removed in machining operations and the weaker center wall material is exposed.

The advantages of this method are:

1. Less expensive sand preparation.
2. Less draft allowance in patterns permitting straighter sides on castings.
3. Molds can be stored for any length of time.
4. Permeability of mold permits gas to escape enabling manufacture of thin wall castings.
5. Close dimensional tolerances.

Figure 12 — Special features have been included on this bottom roll bearing for a blooming mill.

Figure 11 — Manganese bronze may be used for large nuts with coarse thread if there is slow speed operation.

6. Fine surface.

The disadvantages of this method are:

1. Initial pattern costs are high and should be defrayed over at least 100 castings per year.
2. Weight limitation between 100-150 lb on bearing.

Bronze bearing application is only as difficult as one wishes to make it. If consideration is given to the following factors, it should be quite easy. Failures are most often caused by the following:

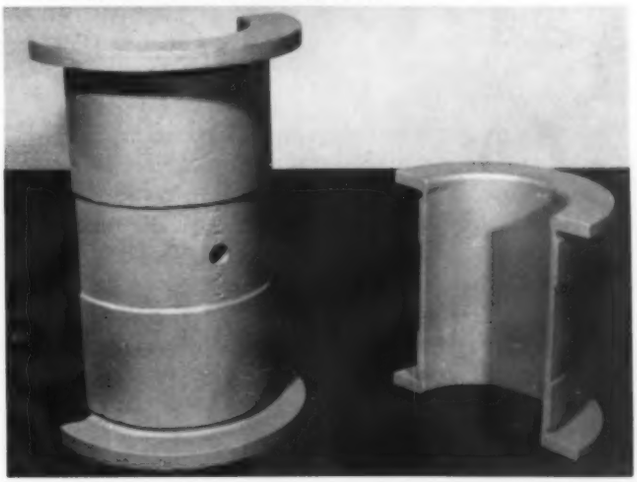
1. Extreme heat.
2. Poor lubrication.
3. High speed.
4. Excessive scale or dirt.
5. Excessive distortion of shaft or journal.

If constant failures are noted, the logical steps to pursue are:

1. Visual analysis.
2. Analysis of metallurgical and chemical properties.
3. Review of design, load and lubrication.

No one bronze and no one design can be considered best for a particular application. The balance between life performance and cost as a primary requirement varies from one application to another. The bearing material is only one part of the unit we call a bearing, so its choice is ultimately related to design and maintenance.

Figure 13 — Cast-to-size bearings are commonly being manufactured by the washed sand mold process and the phenolic resin shell process.



CRANE POWER LIMIT SWITCHES

By R. W. GRAHAM
Superintendent, Electrical Department
Bethlehem Steel Co.
Lackawanna, N. Y.

. . . . a well-thought out design, careful operation, and constant maintenance are essential to keep down failures in limit switches . . . .

▲ABOUT five years ago the Association of Iron and Steel Engineers Standardization Committee suggested that it might be possible to include in their agenda an attempt to standardize on "crane power limit switches." The writer was asked to develop what data was available and to report to the standards committee.

As this question was also an active topic on the National Safety Council for information on the "Seven Company Accident Exchange," they encouraged the analysis of troubles on crane limit switches and were anxious to know what could be done to improve them, either by design, application, instruction to operators, or more rigid inspection and better maintenance. It is a well recognized fact that overhead travelling cranes and falling hook blocks have resulted in many accidents (some fatal) and that anything that would be an improvement over present practice would be time and energy well spent.

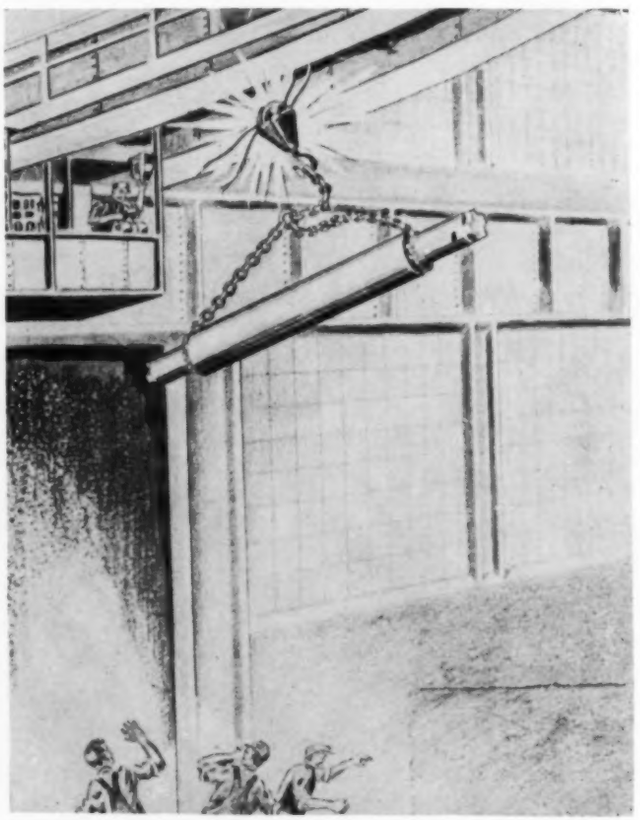
A questionnaire was sent to the various steel plant operating departments, crane builders and manufacturing companies, to determine the features they desired or would prefer if it were possible to standardize on this equipment.

At present there are only two manufacturers of this type of equipment, each of whom, recently, has made rather radical changes in his equipment, and the market for this apparatus is rather limited. The reluctance of these manufacturers to alter dimensions to make an interchangeable piece of equipment with its attended cost of design and dies to make this possible, can be readily seen. However, the committee felt if another control builder did enter the field, the information gleaned from this survey could be applied to place a better crane power limit switch on the market.

As the standardization committee viewed the problem, the results of the survey should be passed out to the steel operating people for what benefit they would receive from it.

The result of the survey, at least, brought to the attention of the operating people some of the troubles

Figure 1 — Limit switch failure may result in costly accidents in the plant.



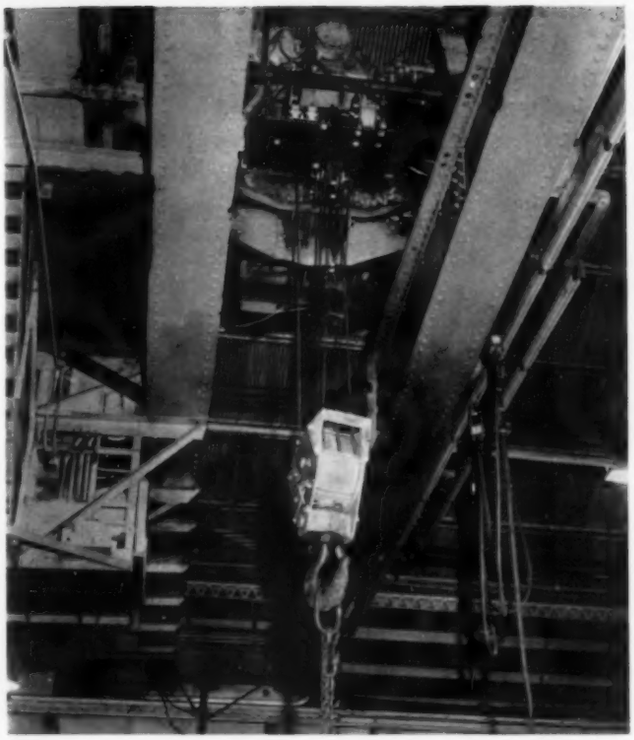


Figure 2 — Some old cranes which were not designed with limit switches resulted in makeshift installations which sometimes caused trouble.

experienced in the various plants and the recommendations which might be applied to eliminate these failures. If we have done this and saved a few lives by calling attention to the application of proper limit switches and the importance of proper maintenance of crane power limit switches, we feel we have accomplished something worthy of the time spent on it.

The inquiry covered such items as:

1. Number of cranes equipped with power limit switches.
2. Failures, per year, of limit switches.
3. Causes of limit switch failures.
4. If a new limit were available, what are some of the points you would improve on?
5. Can we improve on circuits presently available?
6. Difficulties experienced in present wiring schemes due to operators mishandling controls.
7. Proper mounting location of limit switches.
8. Proper application of tripping appurtenances.

Results of the survey covered steel plants with a total of 5025 overhead travelling cranes.

Failures per year were 207, or roughly, one failure for every 25 cranes. We know that if this many were reported there were also many other failures which were not reported.

Some of the reasons given for causes of limit switch failures are as follows: faulty maintenance was responsible for 67 cases; faulty limit switch design was responsible for 34; failure of tripping mechanism or its connections resulted in 51; unauthorized cutting out of limit switches by operating or maintenance personnel, caused 55 failures.

From these replies, it is obvious to men in the operating and maintenance departments that they have a big job cut out for them to keep the cranes in a safe operating condition. The control engineer, crane designer, and the limit switch manufacturer must also make a concerted effort to improve their equipment and offer better methods in their application.

Accessibility of Crane Limit Switches—Figure 2 is an old photograph and is shown as an example of how a limit switch should *not* be mounted. It does show the steps which must be taken sometimes by operating people when they put a power limit switch on a crane which was never designed to accommodate it. In our modern methods of crane design, where some thought has been given to properly maintained equipment, this limit switch would now be located on top of the trolley where it can be properly and safely maintained (Figure 3).

Mounting must be such that tripping action will be positive regardless of any swaying of the block due to any of the crane motions, or regardless of any lateral movement of trolley or crane on the rails.

The mounting has generally been left to the purchaser of the crane and the whim of the people who put the crane in service.

There are several ways of attaching the tripping block to the hook, and erectors have not always used

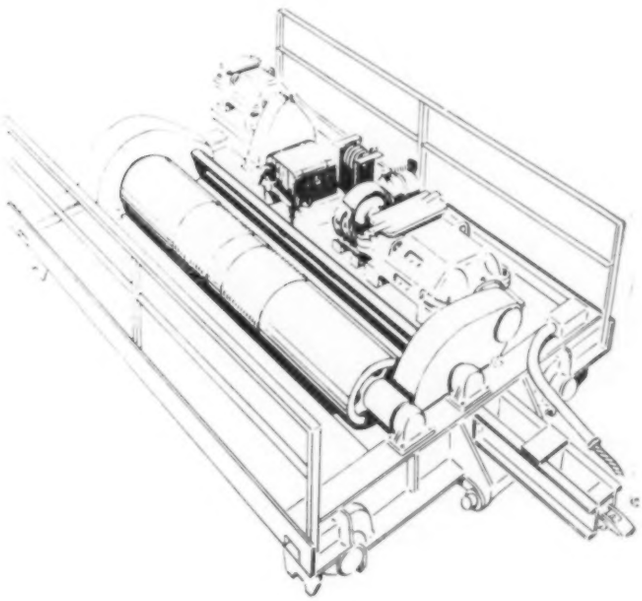


Figure 3 — Limit switch should be located on top of trolley for ease of maintenance.

the best judgment in picking out the cables to which the tripping block is attached. The suspended weight should have plenty of clearance and, if possible, should be suspended on the stationary rope. This will keep the rope from wearing and prevent the false tripping caused by friction between the rope and the suspended weight.

The old principle of failing "safe" would dictate that block should be attached to a "dead" cable, if possible. If not possible, it should be attached to the slowest moving rope which is travelling in a down direction when a load is being hoisted. This position will keep taut the cables which control the counterweight and give the limit switch counterweight less chance to foul.

In a check made some years ago on fifty-eight erected

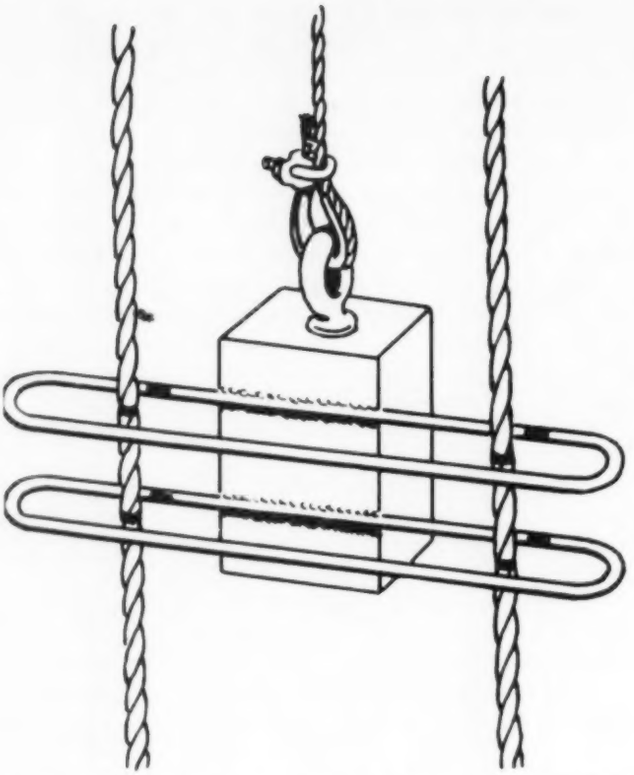


Figure 4 — Counterweight should be so attached that the clamp covers at least two cables.

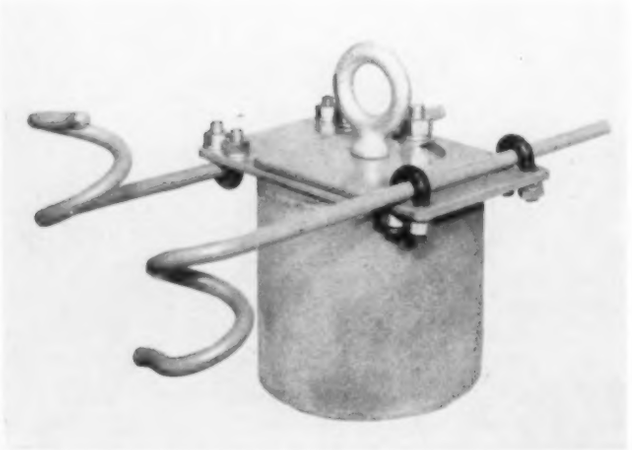
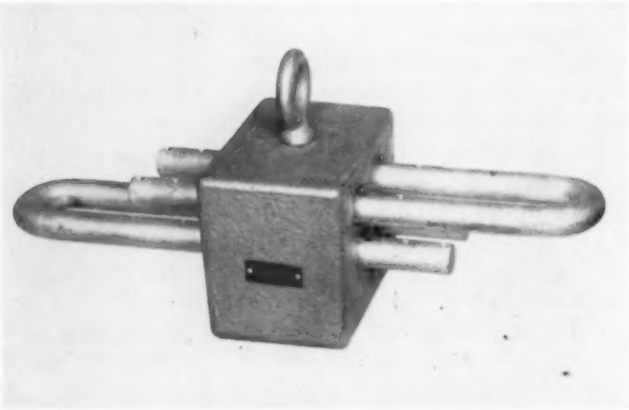


Figure 5 — This design shows a helical type weight which rides on two cables.

▲

Figure 6 — This design shows a hairpin type weight which rides on two cables.



cranes, we found thirty-two which had counterweights on cables going the wrong direction.

Perhaps the manufacturer has more or less left the attachments to be made up to the operating people. We believe the counterweight should be attached with a clamp covering two cables, rather than one, which prevents some fouling up. In some cases involving considerable side pulling, clamps on four cables may be desirable— (Figure 4, 5, and 6).

For various arrangements of attachments for renewed study, the paper by C. G. Dimitt, in the 1944 AISE Proceedings ably describes the various methods of attachments of limit switches to counterweights and cables.

Space for limit switches should be provided by crane manufacturer with the operating weight directly over the hook to take advantage of the proper length of the operating arm, and to take best advantage of balance of forces without necessitating additional sheaves or pulleys with their uncertain friction load, which often causes failure in operation of a limit switch.

The modern crane with roller bearing drums and shafts presents a difficult problem when operating in old buildings with limited headroom, which calls for close settings of limit switches. With a series motor which speeds up when loaded or an empty hook travelling at full speed, a too rapid dynamic braking may cause the motor to flash over when the limit switch trips. See Figure 7.

Let us consider a simple circuit showing dynamic braking in "hoisting" direction which takes place when the limit switch is tripped and plant power is cut off the motor. The limit switch closes into circuit with the motor counter emf supplying voltage for dynamic braking.

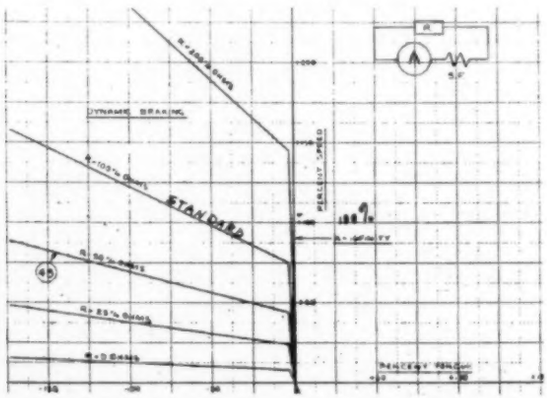


Figure 7 — Too rapid dynamic braking may cause the motor to flash over when the limit switch trips.

The effective effort to stop the load quickly is governed by the ohmic value of the dynamic braking resistor. The lower the ohmic value the more vicious is the sparking. Some control manufacturers have recognized this in roller bearing cranes by increasing this basic resistance from (½) E/I to E/I where "E" is counter emf volts and "I" is armature current. This, again, is working in the wrong direction for quick stopping of the hoist. Possibly a compromise of (¾) E/I could be adopted.

Typical speed torque curves for emergency dynamics braking with various values of this basic resistance can be found in manufacturers' engineering bulletins and is beyond the scope of this paper.

Another feature offered by control manufacturers which the writer believes could be used to good advantage, is an additional "teaser" field resistor TR connected at the limit switch on the trolley. See Figures 8, 9, and 10. This resistance with approximately (8) E/I and a current-carrying capacity of one-sixth to one-eight full-load current would reduce the top speed on light hook as much as 50 per cent, with a corresponding reduction in the kinetic energy to one-fourth.

The study of these relations is worth considerable effort, but again this is beyond the scope of the paper.

Some of the features brought out in the questionnaire are:

That the resistor may be specified either open or closed in a drip-proof housing.

Resistors for dynamic braking should be of the nonbreakable corrosion-resistant type to insure that the proper dynamic braking circuit is closed when called upon to function.

All operating mechanisms, except the operating lever and weights, should be in an enclosure of NEMA 1A, or better. Covers should be secured to the case by a safety chain.

Extended leads should be double-pole, double-throw, arranged to open both sides of the main power circuit, and designed to connect the circuit from dynamic braking through a resistor.

Each pole of the switch should be provided with a magnetic blowout. Switch should be gravity or spring tripped, and gravity reset. Space limitation factor should be determined to make various manufacturers' switches interchangeable. Limit switches should be so located that they are accessible for inspection and maintenance.

Since the questionnaire went out to our own plants, we have had considerable success in eliminating the control type limit switch and using the jackknife wood blocks. Also, we have been able to reduce the number of applications where extra sheaves have been used to actuate the counterweight.

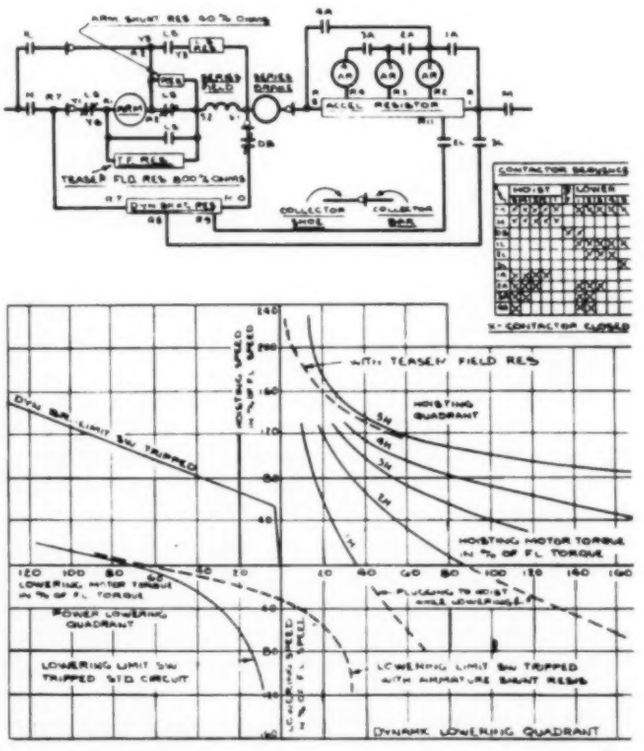


Figure 8 — Diagram shows d-c dynamic lowering control with special teaser field resistor to limit speed.

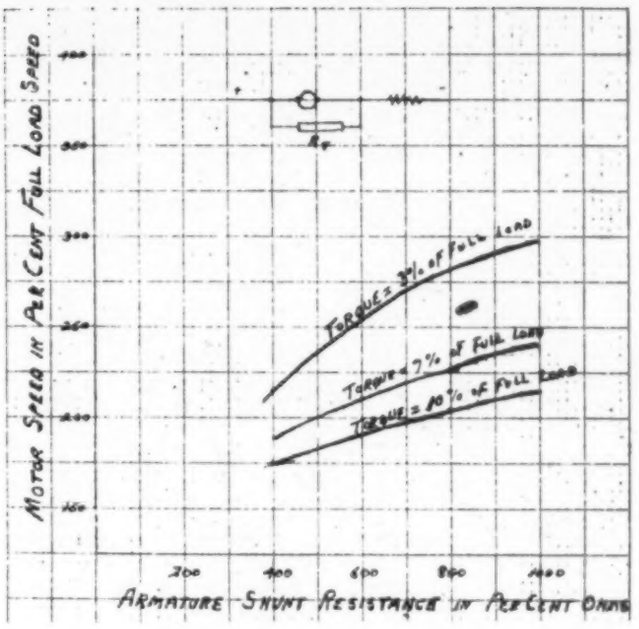

MOTOR SPEED IN PER CENT FULL LOAD SPEED
TORQUE = 3% OF FULL LOAD
TORQUE = 7% OF FULL LOAD
TORQUE = 10% OF FULL LOAD
ARMATURE SHUNT RESISTANCE IN PER CENT OHMS

Figure 9 — Curve shows relation between per cent of full load speed and armature shunt resistance for various torque values.

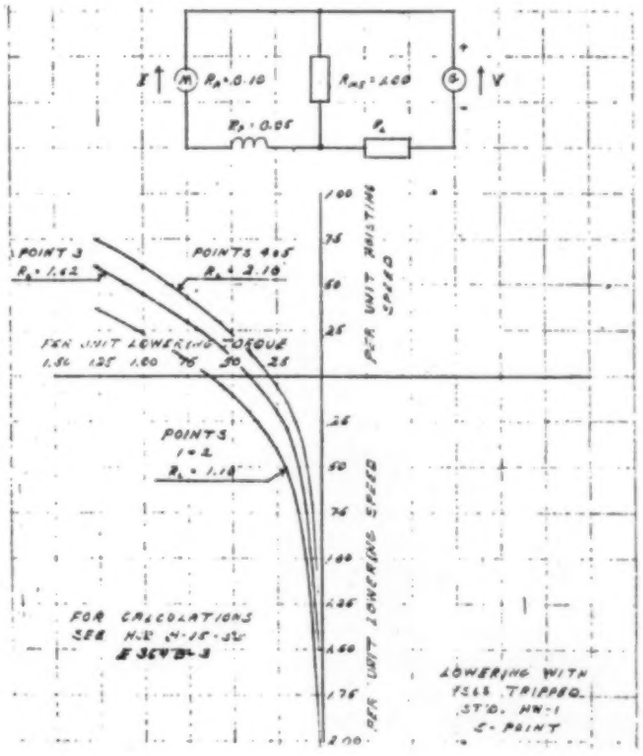


Figure 10 — Curve shows torque speed values for plugging with limit switch tripped.

It is reported that counterweights and guides furnished by limit switch manufacturers are often discarded and home-made designs applied with special guides for at least two and sometimes three or four cables. We generally use the manufacturer's weights, but tailor make the cable guides to fit the particular crane.

Failure of operators to try out limit switches for long periods of time may result in a sticky limit switch which can fail if the operator slowly hoists into the limit switch trip position.

Bearings tighten up from dirt and corrosion and this is especially true of the oilless type bearing. Manufacturers have now recognized this and are equipping present day switches with oil fittings. We are, however, forced to maintain many switches which have no provision for oiling. This calls for added maintenance or removal of switches and fitting them up with provision for lubrication.

From experience we have found that there is no cure-all that can be applied to keep a crane limit switch functioning perfectly all the time, but we do know that good design, a thorough knowledge of the operations and functions of the equipment, frequent tests and inspections, plus good maintenance, will insure reliable operation and decrease the number of limit switch failures.

DISCUSSION

PRESENTED BY

R. J. HARRY, Vice President, Alliance Machine Co., Alliance, Ohio.

JOHN D. LEITCH, Chief Engineer, The Electric Controller and Manufacturing Co., Cleveland, Ohio.

EDMOND B. FITZGERALD, Assistant Division Manager, Industrial Control Sales, Cutler-Hammer, Inc., Milwaukee, Wis.

ALEX F. McLEAN, Works Manager, Canadian Tube and Steel Products, Ltd., Montreal, Quebec, Canada.

R. J. Harry: The information contained in this paper indicates that the author has spent considerable time in trying to ascertain the cause of limit switch failures.

Prior to June 25, 1953, I could not add very much to Mr. Graham's paper, but on that date our company demonstrated a new type of power limit stop which overcomes practically all of the shortcomings of the present power limit switch.

Mr. Graham pointed out that in one year there was reported 207 failures of power limit switches now in use in the steel industry, applying on 5,025 cranes, covered by his survey. This in itself is sufficient evidence that there is room for improvement in this very essential safety device.

The new safety limit stop which we have developed is of very simple construction and consists of a circuit interrupting device which disconnects the motor from the line and employs a group of springs which have the capacity to absorb the kinetic energy of all the hoist revolving parts. This limit stop is installed on a 30-ton crane in our shops and has operated over a hundred times with no injury to the trolley frame or the hoisting ropes. The same hoisting ropes are in use at the present time as were in use at the first demonstration.

John D. Leitch: I would like to discuss further Figure 8 which is that showing the use of special resistors for limiting the motor speed. Mr. Graham referred to the possible use of a "teaser field" resistor having an ohmic value of eight times E/I when E is line voltage and I is the full load current. This resistor has been used successfully in a number of cases where the light hook speed was excessive. In our opinion the use of a teaser field resistor in such a case is worthy of consideration since the light-hook hoisting speed can easily be reduced to twice full load speed. We have known cases where 3½ times full load speed were encountered on hoisting a light hook. This reduction in kinetic energy to $(2/3\frac{1}{2})^2$ or 38 per cent not only permits higher head room but also reduces the wear on the brake linings.

This resistor does not appreciably affect the hoisting speed on loads other than light loads nor does it modify the speed-torque curves in the lowering quadrant to any extent.

On the same diagram there are two other resistors shown connected to the limit switch and mounted on the trolley. The first is the usual dynamic braking resistor which has a value of about E/I. This can be varied from between one-half and one E/I depending on the ability of the motor to commute the higher current. The lower the value of this resistor the stronger the dynamic braking but the higher the armature currents.

The other resistor is referred to as an armature shunt resistor having an ohmic value of about 0.4 E/I. This resistor has no significance as long as the limit switch is in the untripped or normal position. In entering the limit switch during hoisting, its effect on the dynamic braking torque is negligible, but on lowering out of the tripped limit switch, it provides an armature shunt while the standard dynamic braking resistor acts as a motor shunt to a straight series motor connection. The effect of the armature shunt resistor is to reduce the driving down torque so that the limit switch resets before reaching a high speed. This prevents a sudden speed change when the limit switch resets and was particularly useful on older types of limit switches when the resetting distance was greater than those of present design. This change in the speed-torque curve is shown by the dotted curve in the power lowering quadrant.

E. B. Fitzgerald: I wish to compliment Mr. Graham on a very comprehensive paper, and to thank him and his committee for the work they have performed on this project. I believe we will all agree that it has been time well spent, and that the results have been significant.

An overhead traveling crane represents a large financial investment to its owner, and much money may be spent on electrical rotating equipment and complex control schemes to power and protect a crane. However, if the crane safety limit stop, which represents only the smallest fraction of a crane's total cost, is not operating properly, the balance of the electrical equip-

ment, regardless of its complexity, is unable to protect the crane from overhoisting the hook-block and the hazards inherent to this situation. The concept of system engineering, or in other words complete design analysis, should, therefore, certainly be extended to and include a careful study of the installation of the safety crane limit stop.

The percentage of E/I in the limit stop's dynamic braking circuit is somewhat of an empirical figure and much time may be spent discussing the merits of either a high or low resistance value. Obviously, we desire rapid deceleration of the load, which requires a low resistance value in order to obtain a high dynamic braking current. However, excessive dynamic braking currents will eventually damage the commutator of the hoisting motor or at least seriously shorten its useful life.

We believe the correct resistance value for this circuit to be in the range from 50 per cent E/I to 100 per cent E/I depending on the type of hoist motor being employed. For the newer mill type motors, which employ interpole windings, we normally supply 50-60 per cent E/I in the braking resistor. This value permits a high braking current to produce a rapid load deceleration rate, and still maintains the braking current within the excellent commutating ability of the mill type motor. However, when controlling a non-interpole winding mill type motor, or the majority of industrial type motors, it is necessary to provide a resistor value of approximately 100 per cent of E/I in order to keep the braking current within the commutation limitations of these type motors. Naturally, the lower braking current produced by this higher resistor value will not provide the rapid deceleration rate obtained with the 50-60 per cent E/I dynamic braking resistor.

On hoists utilizing straight series wound motors, a teaser field may be used to advantage to limit the dynamic braking current necessary to obtain a given maximum braking distance. The teaser field, which limits the maximum speed of the hoist under light hook conditions, permits the use of a higher value of braking resistor and hence a lower braking current to obtain a specified braking distance even under light hook conditions.

Mr. Graham classified 34 of the limit stop failures investigated by his committee as design failures. A large percentage of these 34 failures in all probability is traceable to bearing difficulties. Corrosive action and dirt in the atmosphere can, over a period of time, foul an unsealed bearing and prevent its proper operation. Also, limit stops on outdoor service and sub-freezing temperatures may experience frozen bearings. For this reason we now furnish all sizes of the crane safety limit stop with sealed, life-time lubricated bearings which we believe will eliminate the vast majority of bearing troubles and satisfy one of the major causes of limit stop failure.

A limit stop when shipped from its manufacturer is in proper operating condition. How long it remains in this condition is entirely dependent upon the maintenance it receives. This is particularly important to limit stops installed on cranes operating under a low head room limitation, where the limit stop is used for service stops as well as for emergency stops. The Gary Steel works and the Pittsburgh works of J. & L. are two mills that follow a highly recommended annual maintenance schedule for limit stops. Under this schedule, each limit stop is replaced annually and returned to the electrical shop, where it is cleaned, and all worn parts are replaced. The limit stop is then placed in a special stock where it is available for installation on the next crane due for annual renovation. The small additional cost of this very complete maintenance program is certainly more than justified by the hazards it prevents.

Alex F. McLean: One type of failure which might be of interest to some people, has occurred when the operator was hoisting a light hook at full speed. In stopping the hook he has inadvertently moved his controller to the No. 1 hoist position rather than the "off" position. In the circuits used on these cranes, the magnetic brake is held inoperative in this position despite the opening of the crane limit switch. The result was that the hook coasted through due to the inertia of the rotating parts and the crane cable broke, dropping the block.

I am interested in this development of spring stops as it might be a means of preventing accidents of this kind on cranes equipped with this circuit.

John D. Leitch: I would like to refer to Mr. McLean's remark regarding the use of a motor shunt on the first point hoist and what happens if the controller is returned to this point at the instant the limit switch is tripped. Under such a condition, the brake does not set but is held released.

We abandoned the use of this connection some four or five years ago. However, it is useful in limiting the speed when taking up slack cable, and we have some customers that insist upon its use today, in spite of the fact that it has the disadvantage mentioned.

Are you annoyed by having someone borrowing your magazine when you want it?

Get him to join the AISE.

A Safety Limit Stop

By R. J. HARRY
Vice President
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. . . . the mechanism described provides a mechanical means to stop hook block without accidents . . . .

▲ ABOUT a year ago the writer was asked to come to Pittsburgh to discuss with safety engineers, a device developed to prevent the dropping of the hook block in case of failure of the limit switch. This device consisted of a group of mechanical latches which would catch the hook block and prevent it from falling after the hoisting ropes were broken.

While this device had some inherent faults, it was an attempt to overcome a major hazard in the operation of electric overhead traveling cranes and as such, the originator of this scheme is to be commended for his efforts to promote safety in industry.

Before this latching device is brought into operation, the hook block has to be run up and the hoisting ropes broken. When one considers that the safety factor of the hoisting ropes on an average crane is 5, and as much as 10 on hot metal cranes, the forces required to break the hoisting ropes are of great magnitude. Take for example, a standard 10-ton E. O. T. crane, having a factor of safety in the ropes of 5. The hoisting mechanism is, therefore, subject to stresses resulting from a force of 50 tons which is required to break a new hoisting rope. In many cases, the stresses incurred from this 50-ton force, result in permanent injury to the trolley structure and could conceivably render the latches inoperative. It also introduces a hazard when men are required to release the hook block from the very inaccessible position after the hook block has been run up and caught after a rope breaks. Even if the device did work perfectly, it would be necessary to install a new hoisting rope, a procedure which requires considerable time and additional cost. There is also the danger of the swinging hook block not engaging the latching device when the hook block is run up, and as a result the hook block would fall after the rope is broken.

Due to the fact that the hook block has to be raised a considerable distance higher than the latching device in order to allow the latches to set properly, there is bound to be an impact load imposed upon the latching device when the ropes break. This impact would be greatly increased when there was a load on the hook, and it could cause failure of the latching device if the latches and their supporting members were not adequately designed.

The Association of Iron and Steel Engineers and the National Safety Council have encouraged and assisted electrical manufacturers in the improvement of designs of the present power limit switches and are always on the lookout for apparatus that will result in fewer accidents.

About five years ago, Mr. R. W. Graham was assigned the task of standardizing crane power limit switches by the Association of Iron and Steel Engineer's Standardization Committee. Summarizing Mr. Graham's report, failures were classified as follows:

Faulty maintenance	67
Poor design	34
Failure of tripping mechanism	51
Unauthorized cutting out of limit switch by operating or maintenance personnel	55
Total	207

Mr. Graham has, therefore, given 207 good reasons for improving the present power safety limit switch. In an effort to overcome the failures, the writer developed a hoist limit stop which involves a principle different from any now in use.

This new hoist counter-torque limit stop is applied to a 30-ton crane in our shop and was demonstrated before a group of 250 engineers, on June 25, 1953. Up to the present time, the hook block on this crane has been jammed at least a hundred times with no injury to the hoist or the trolley frame, and the same hoisting rope is uninjured and still in use.

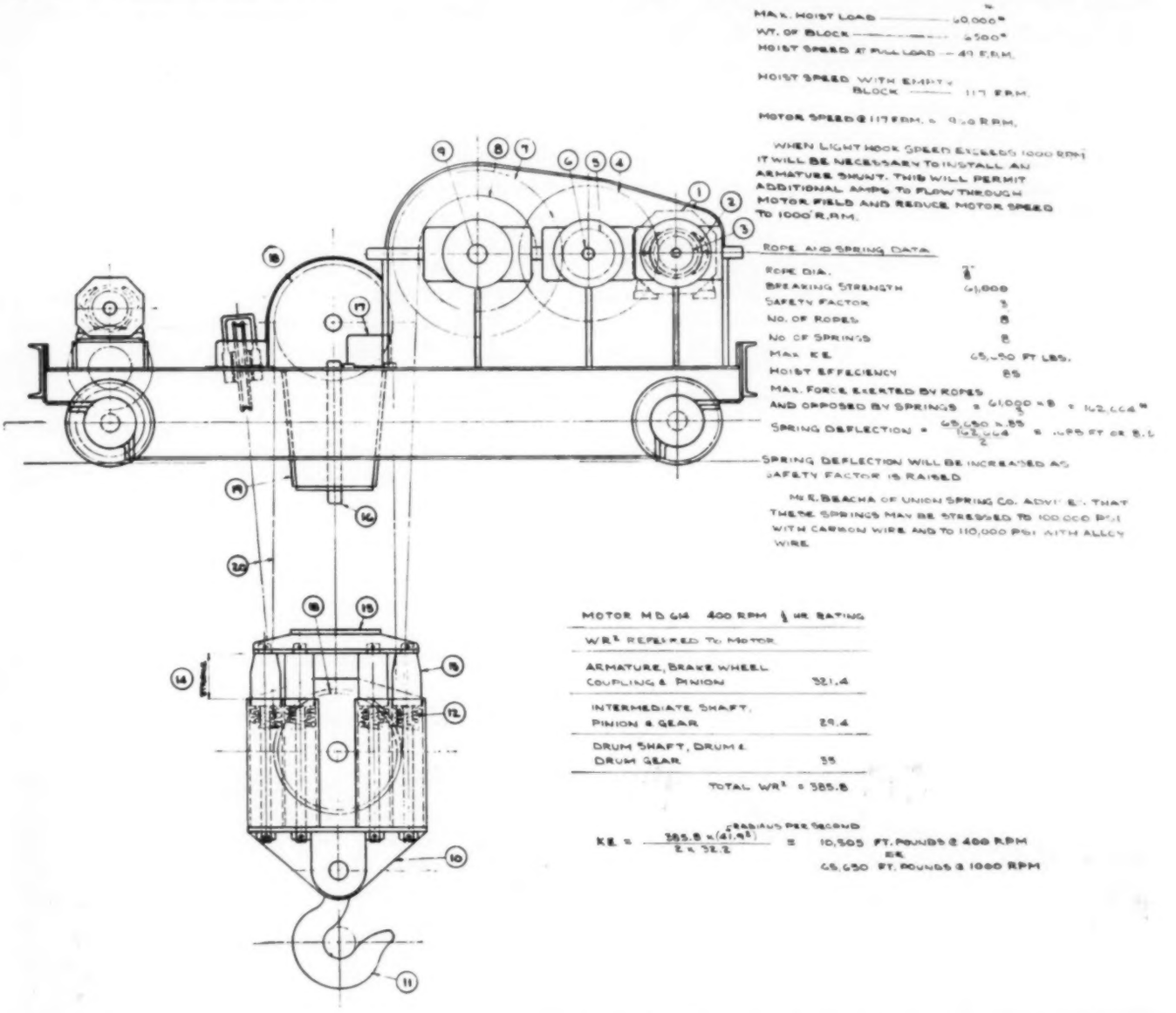

MAX. HOIST LOAD — 60,000#
WT. OF BLOCK — 4500#
HOIST SPEED AT FULL LOAD — 40 R.P.M.
HOIST SPEED WITH EMPTY BLOCK — 117 R.P.M.
MOTOR SPEED @ 117 R.P.M. = 900 R.P.M.
WHEN LIGHT HOOK SPEED EXCEEDS 1000 R.P.M. IT WILL BE NECESSARY TO INSTALL AN ARMATURE SHUNT. THIS WILL PERMIT ADDITIONAL AMPS TO FLOW THROUGH MOTOR FIELD AND REDUCE MOTOR SPEED TO 1000 R.P.M.
ROPE AND SPRING DATA
ROPE DIA. 7/8"
BREAKING STRENGTH 61,000
SAFETY FACTOR 5
NO. OF ROPES 8
NO. OF SPRINGS 8
MAX. K.E. 65,650 FT. LBS.
HOIST EFFECIENCY 85
MAX. FORCE EXERTED BY ROPES AND OPPOSED BY SPRINGS = 61,000 × 8 / 2 = 142,664#
SPRING DEFLECTION = (65,650 × .85) / 142,664 / 2 = .195 FT. OR 2.3"
SPRING DEFLECTION WILL BE INCREASED AS SAFETY FACTOR IS RAISED
MR. E. BEACHA OF UNION SPRING CO. ADVISES THAT THESE SPRINGS MAY BE STRESSED TO 100,000 PSI WITH CARBON WIRE AND TO 110,000 PSI WITH ALLOY WIRE
MOTOR MD 6M 400 RPM ½ HR. RATING
WR² REFERRED TO MOTOR
ARMATURE, BRAKE WHEEL COUPLING & PINION 321.4
INTERMEDIATE SHAFT, PINION & GEAR 29.4
DRUM SHAFT, DRUM & DRUM GEAR 35
TOTAL WR² = 385.8
KE = 385.8 × (41.9)² / 2 × 32.2 = 10,505 FT. POUNDS @ 400 R.P.M.
KE = 65,650 FT. POUNDS @ 1000 R.P.M.

Figure 1 — Design calculations for selecting springs are shown in schematic sketch of load absorption mechanism.

In the design of this counter-torque limit stop, every effort was made to produce a device that would be simple in construction and operation.

This limit stop consists of two major parts: (1) a contactor or circuit breaker, mechanically tripped, which is used to disconnect the motor, (2) a group of springs, located on the hook block or on the trolley which are used to absorb the kinetic energy of the revolving parts of the hoist, consisting of the armature, brake wheel, gearing drum, shafting, etc.

Mr. Graham, in his investigation of failures of hoist power limit switches, found that these failures fell into four classifications. Of the 207 failures he found that 67 of these failures could be attributed to faulty maintenance. Since this new hoist counter-torque limit stop has only two major working parts, the chances of failure are very remote. The contactor or circuit breaker is mechanically tripped at the instant the hook block is brought into contact with the upper supporting beam of the trolley. Since most of the limit switch failures occur under light-load or no-load conditions, the circuit breaker is called upon to interrupt only a small portion of the full-load current of the motor. This circuit breaker or contactor is enclosed to protect it from the dirt, and its only duty is to open the motor circuit. Immediately after the motor circuit is interrupted, the springs, located either on the hook block or in the upper lifting beam are brought into action. As these springs are compressed, the hoisting mechanism is slowed down and finally brought to a stop, the springs being so designed that the hoisting mechanism is brought to a stop before the springs are compressed solid. Therefore, there are no trick circuits required, such as dynamic braking to slow down the armature, neither do we depend on the action of the brake or brakes to bring the armature to rest. Since the circuit breaker is used simply to open the motor circuit, usu-

ally under very light load conditions, it should last indefinitely with a minimum of maintenance, and since the springs, if properly designed, are never stressed beyond the elastic limit and never compressed solid, they should last indefinitely, with practically no maintenance.

Mr. Graham's second classification of limit switch failures was poor design, which accounted for 34 failures. In the hoist counter-torque limit stop under discussion, the design is very simple. The contactor or circuit breaker is chosen with a capacity to handle the motor current. The springs, however, have to be carefully calculated to obtain the correct pressure and stroke to absorb the kinetic energy of the hoist mechanism and at the same time not exceed a predetermined rope load.

The third classification of limit switch failures was that of the tripping mechanism which accounted for practically 25 per cent of the total failures reported. Since the counter-torque limit stop under discussion has no weights hanging on cables which must be lifted by the hook block so that the second counterweight can actuate the standard limit switch, and since no dynamic braking circuits need be set up, and since no assistance from the brakes is required, no tripping mechanism failures should be expected on the hoist counter-torque limit stop under discussion. The striker plate located on top of the hook block engages a plunger when the hook block is run up and trips the circuit breaker, thereby providing the most reliable tripping device possible. If the plunger is not in position, the circuit breaker must be open and the hoist cannot operate. The plunger that trips the circuit breaker must, therefore, always be in the proper position when the crane is operating. In regard to the springs, they are always ready for instantaneous action, and require zero time to start counter-torque action on the revolving hoist mechanism.

The fourth classification of limit switch failures, that of unauthorized cutting out of limit switch by operating or maintenance men, accounted for 55 of the failures of the standard power limit switch. With the standard power limit switch lift is sacrificed to operate the limit switch and to bring the hoist motor to rest. The greater the hoisting speed, the greater is the amount of lift that must be sacrificed. When the maximum lift is required, it is sometimes necessary to temporarily cut out the standard crane limit switch. As the result of this action, failures often occur when this limit switch is not put back into service. With the hoist counter-torque limit stop under discussion there is no reason to cut out the limit stop as the hook block is brought into contact with the trolley frame every time the hoist counter-torque limit stop is brought into action. Since nothing is gained, therefore, by cutting out the hoist counter-torque limit stop, and no extra height of lift is accomplished, there is no reason for cutting out this hoist counter-torque limit stop and as a consequence failure from this source should never occur.

The type of motor customarily used on cranes in steel mills in this country is the direct-current series motor. The series motor is a varying speed motor, the speed varying inversely as the load. In the present case, the armature has a speed of 400 rpm based on the ½-hour rating or crane rating of the motor. At this speed

Figure 2 — A bumper plate is used to transmit the load to the springs.

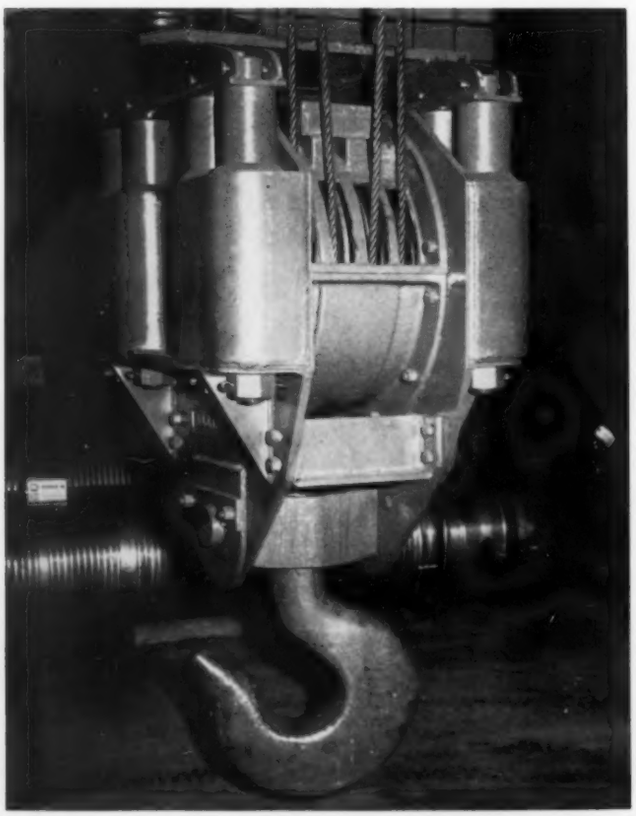
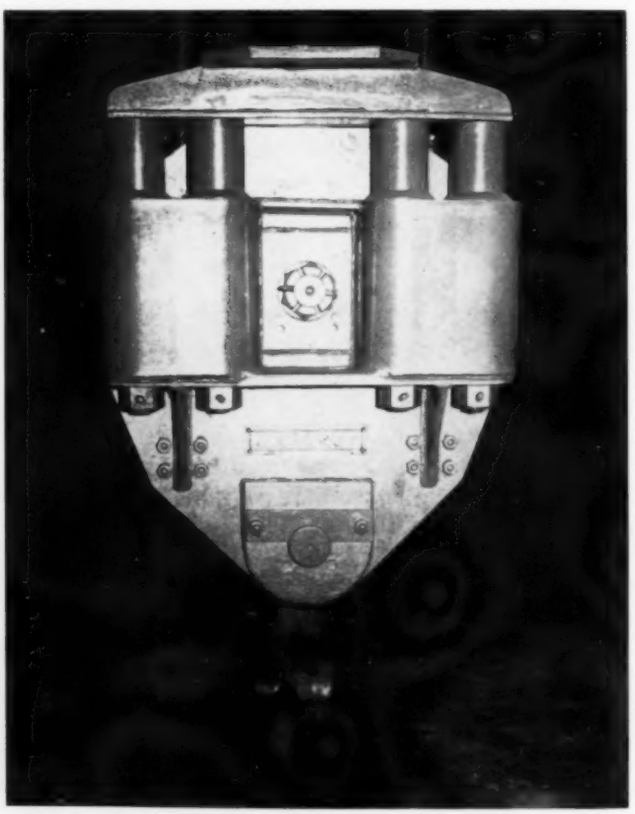


Figure 3 — Design of mechanism is extremely simple and is easy to maintain.



the foot pounds of energy stored up in the armature, brake wheel pinion and coupling amount to 8,750 foot pounds. The intermediate shaft, on which are mounted gear No. 4 and pinion No. 5, has 800 foot pounds of stored energy when the armature is operating at 400 rpm. The drum shaft, No. 9, upon which are mounted drum No. 8 and drum gear No. 7, has 955 foot pounds of stored energy when the armature is operating at 400 rpm.

The total energy stored up in the revolving parts of the hoist, therefore, amounts to 10,505 foot pounds when the motor is revolving at 400 rpm.

As stated before, a series motor is a varying speed motor whose speed varies inversely as the load. Therefore, under light-load or no-load conditions, the armature often attains a speed of 2½ times the ½-hr rating, and since the stored energy in the revolving parts varies as the square of the speed, the total kinetic energy stored up in the revolving parts would be the square of 2½ or 6¼ times the 10,505 foot pounds of energy at 400 rpm, making a total stored energy of 65,650 foot pounds at 1,000 rpm.

The breaking strength of a new ⅞-in. rope is 61,000 lb on the basis of using plow steel hoisting rope, having six strands of 37 wires each and hemp center. With a factor of safety of 3 in the ropes, it is possible to load a ⅞-in. rope to 20,333 lb. Since, in example shown, there are eight ropes, we obtain the maximum force applied by the eight ropes to the group of springs by multiplying the maximum safe load of one rope by the number of ropes, or 20,333 x 8=162,664 lb. Since the force exerted by the springs varies from 0 to 162,664 lb, the average force exerted by the springs is

$$\frac{162,664}{2}=81,332 \text{ lb.}$$

The deflection of the springs to absorb the kinetic energy of the hoist revolving parts is, therefore,

$$\frac{65,650}{81,332} \times 0.85=0.69 \text{ ft or } 8.2\text{-in.}$$

In figuring the necessary springs to absorb the kinetic energy of the revolving hoist mechanism, care must be exercised not to exceed the safe load on the hoisting ropes. In the example above we have used a factor of safety of three. In some cases a higher factor of safety may be desirable. Since the energy absorbing power of the springs is a function of the maximum safe load that can be applied, times the stroke, it is necessary to select springs whose deflection stroke is sufficient to prevent the maximum spring pressure breaking the ropes. For instance, if the springs are designed to give a factor of 4 in the ropes, the stroke of the springs will be 10.8-in. as per example:

Safety factor of 4 in ropes $\frac{61,000}{4}=15,250=1$ rope.

Maximum force exerted by 8 ropes and opposed by springs $=8 \times 15,250=122,000$ lb.

Average force exerted by springs $=\frac{122,000}{2}=61,000$ lb.

Deflection $=\frac{65,650}{61,000} \times 0.85=0.91$ ft or 10.8 in.

In most cases the weight of the hook block will prevent a series motor from attaining a speed greater than 2½ times the ½-hour rating or crane rating of the motor. In case it does not, however, it is a very easy matter to apply a relatively high ohmic value resistor across the armature terminals which will increase the ampere turns in the field and prevent the motor from attaining a speed greater than 2½ times the ½-hour rating under no-load conditions.

In the case of a-c cranes, where the hoisting speed never exceeds the synchronous speed of the motor, the application of springs to absorb the energy of the revolving parts of the hoist becomes a much more simple question, and the springs do not need to be as heavy as in the case of a d-c series motor, unless high-speed a-c motors are used.

At the present time, practically all the electric overhead traveling cranes are equipped with electrical power type limit switches. These switches are normally actuated by the hook block and in almost every case is a very effective means for preventing over-travel of the hook block. There are occasions, however, where for lack of proper maintenance or failure of the operating or trip mechanism, the limit switch is rendered inoperative, and under these conditions, if the controller is not moved to the "off" position in sufficient time, the hook block is brought into engagement with the lifting beam of the trolley resulting in the inertia of the revolving parts, breaking the hoisting rope and dropping the hook block to the ground, often with fatal results.

While the hoist counter-torque limit stop can be used alone on crane hoists, the ultimate in safety can be achieved by using the hoist counter-torque limit stop to supplement the present power safety limit switch, so that in case of its failure the counter-torque limit stop would absorb the kinetic energy of the hoist revolving parts and bring the motor to a stop without breaking the hoisting ropes.

In the operation of the hoist counter-torque limit stop, the sequence is as follows:

First, the motor circuit is interrupted, thus reducing the energy to be absorbed by the springs. The springs then are brought into action, starting with zero resisting force and increasing uniformly as the hoisting mechanism and motor are brought to rest. Therefore, the action which takes place in a fraction of a second and appears to be an impact collision between the hook block and the upper lifting beam, really is a cushioned blow, starting at zero force and increasing as the springs are compressed and the hoist motor brought to rest. The motor circuit interrupting device can be either a standard control contactor equipped with a mechanical trip, or a standard mechanical trip circuit breaker.

We are of the opinion that this circuit interrupting device should be enclosed and the door providing access to the resetting mechanism, locked. This opinion is shared by a number of safety engineers who have been consulted in this matter. This arrangement makes it necessary for the crane repairman to reset the circuit breaker when the craneman trips the limit device and affords him an opportunity to inspect the crane for cause or damage. It is possible that some plants will demand a resetting device that can be operated by the craneman from the cab. This can be easily accomplished if desired.

It is also possible that some engineers will demand that the circuit interrupting device be double pole, thereby completely isolating the motor from the power source, although we have had perfect performance with single pole circuit interrupting devices.

At this point it is proper to ask, "What can cause failure of this new limit stop?" If properly installed, there should be no reason for failure of the limit stop itself. However, since the hoist counter-torque limit stop is brought in action by the hoisting ropes, these ropes should be examined at stated periods, as is required at many plants, and changed when necessary. If the hoisting ropes are allowed to operate for too long a period and the breaking strength reduced too much, it is possible to break the hoisting rope during the normal operation of the counter-torque limit stop. While this failure would in no manner injure the crane, the falling hook block might cause a fatal accident.

The Association of Iron and Steel Engineers should, therefore, standardize on the factor of safety of the hoisting ropes when the counter-torque limit stop is used.

In the demonstration on the 30-ton crane at our plant, we have used a factor of safety of 3 in the ropes when the limit stop functions. This means that when the hoisting ropes are new and the hoist is designed with a factor of safety of 5, for a 30-ton crane, the ropes will break when loaded at 150 tons. The counter-torque limit stop when designed to give a factor of safety of 3 will *never* impose a load greater than 50 tons on the hoisting ropes. In order to operate safely, the hoisting ropes should never be allowed to reduce in capacity to less than 50 per cent of the rated new capacity. This would mean that the hoisting ropes when worn would have a breaking strength of 75 tons while the counter-torque limit stop could impose a maximum of 50 tons on the hoisting ropes.

In order to obtain the ultimate of safety in the application of this hoist counter-torque limit stop, the Association of Iron and Steel Engineers should establish by actual test, the average percentage of strength of a worn hoisting rope as compared with a new rope. With this information available, the counter-torque limit stop can be designed to give safe, dependable operation.

CURRENT AISE DISTRICT SECTION MEETING NOTICES

BIRMINGHAM SECTION

No Meeting.

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BUFFALO SECTION

Tuesday, June 8, 1954, Golf Party.
Wanakah Country Club, Wanakah, N. Y.

▲

CHICAGO SECTION

Tuesday, June 8, 1954, Golf Tournament.
Gary Country Club, Gary, Ind.

▲

CLEVELAND SECTION

No Meeting.

DETROIT SECTION

No Meeting.

▲

PHILADELPHIA SECTION

No Meeting.

▲

PITTSBURGH SECTION

Friday, June 4, 1954, Golf Party.
Sunnehanna Country Club, Johnstown, Pa.

▲

YOUNGSTOWN SECTION

Saturday, June 26, 1954, Golf Party.
Mahoning Country Club, Girard, Ohio.

NEW SOAKING PIT FACILITIES AT STEEL DIVISION OF FORD MOTOR COMPANY

By B. D. BARNS
Supervisor

and

H. E. RAAFLAUB
Senior Fuel and Utilities Engineer

Fuel and Utilities Department, Steel Division, Ford Motor Co., Dearborn, Mich.

. . . . a number of difficult problems had to be solved in this soaking pit installation . . . .

▲ IN the years since World War II ended, Ford Motor Co. has spent $900,000,000 to modernize and expand. More than 26,000,000 sq ft of floor space has been added to its manufacturing facilities. The company's steel division has undergone major changes as part of this over-all program. A new blast furnace was built to supply more hot metal to the open hearth. Three new open hearth furnaces were built and several of the other seven furnaces were rebuilt, causing the output of the open hearth to practically double.

These changes brought about a bottle neck in our blooming and mold stripping operations. The problem was further complicated by the available room and the topography of the open hearth and soaking pit facilities. The open hearth furnaces are located in a line, north and south, while the pits lie east and west at the north end of the open hearth. To the north of the pits lie operations which would limit the available room in that direction. Within the soaking pit building were fifteen regenerative and eight recuperative pits.

Two larry cars transferred ingots from the open hearth to the soaking pit building. Each car could hold from four to six ingots, therefore considerable shuttling was necessary to bring one heat to the pits.

A new stripper building was planned to allow the stripping of the ingots so that the mold buggies could be brought directly to the soaking pits. This in itself presented a problem as two tracks would be required in the soaking pit building to eliminate switching congestion. Therefore, the problem of room was paramount as at the time only one track was available and no ingot storage within the building was possible.

The lack of room to the north, east or west of the soaking pit building dictated the final outcome of our planning. Sufficient capacity would have to be built within the present limitations, and still give us the track, storage, and production facilities necessary to meet the expanded ingot production.

Pit cover cranes could not be used as they would require some of the necessary storage space. Individual covers were adopted because they would roll back toward the existing lean-to control balcony. By eliminating approximately six feet of the lean-to balcony, the cover problem was overcome without sacrificing precious room. Space further dictated the present pits as the recuperators could be tucked away under the lean-to balcony, otherwise this would have been dead space.

The problem of control equipment also figured into the cramped area. To put this equipment on the ground floor would have made it inaccessible to the operating people. The hazards of destruction by moving equipment on the ground level would have been great. The only available space was the heating balcony, but again we were limited by space. It was decided to house the electrical and combustion control equipment all with-

Figure 1 — Ingots are now brought to the soaking pits on two railroad tracks. Ingot buggy tracks are adjacent and permit the ingot to be deposited on the blooming mill table roll in foreground.

in one cubicle. The only separate unit would be the hydraulic controls for each block.

The outer face of the control house would carry all the combustion meters and pyrometers. The electrical breakers and switches would be housed inside. Because of the fire hazard prevalent within the control house, no combustible material was terminated at the panel. All gas differentials and pressures were transmitted from their source to the control panel by air pressure. The hydraulic equipment was controlled electrically or pneumatically from the panel board.

The original pits in the building consisted of five batteries of three regenerative pits and four batteries of two recuperative pits. The regenerative pits were old pits and their capacities were unsuitable for the future planned production. The eight recuperative pits were relatively new pits. They were two-way fired with the burners located low in the pits.

Considerable thought was given to revamping the recuperative pits to meet the coming demand. The burners, being in the position they were in, dictated that the expected large ingots could not successfully be heated in these pits. It was found that the cost of making the pits over-fired would be considerable. Furthermore, since they were equipped with a cover carriage, much of the necessary room would be unproductive.

Three of the recuperative batteries were located at the extreme west end of the building. The fourth was at the extreme east end of the building. The location of the fourth battery precluded that it would have to be removed regardless. Therefore, due to the location, and the room they required, and the cost of revamping, the firing equipment, the recuperative pits, as well as the regenerative pits were removed.

Five blocks of four pits were installed to increase the undercover capacity from 1240 tons to 2000 tons in approximately 60 per cent of the total available space. The remaining 40 per cent was left for ingot storage and cover repair bays.

The new pits are twenty-five feet long, eight feet wide, and fourteen feet deep. Because of their length, it was possible to move the ingot buggy north a sufficient distance to allow two railroad tracks to be laid. These two tracks will allow two strings of ingots to be brought to the soaking pits. A third track will enter the pit building as far as the cover repair bay for cold ingot storage.

The inner walls of the pits are built of silica stone eighteen inches thick. This stone is backed by four and one-half inches of insulating brick. Between the insulating brick and the metal casing is two and one-half inches of insulating flake. This makes a total of seven inches of insulation.

All the pit covers are of sprung arch construction. Four covers were constructed of a light weight 2800 F brick. The remaining covers are constructed of semi-silica brick.

The burner is located in the north wall two feet, seven inches below the top of the coping tile. It is a cluster type burner consisting of four four-inch pipes projected through a venturi. The flow of combustion air is measured across this venturi. The burner and venturi assembly is tilted upward three degrees from the horizontal. The temperature measuring unit is located in the center of the south wall, six feet, four inches below the top of the coping tile.

The combustion air for a battery of four pits is initiated by a blower pumping 3600 cfm of air at 56 ounces. This air is blown to a metallic recuperator where its temperature is raised to 800 F. After leaving the metallic recuperator it is blown through a jet pump. This primary air inspirates secondary air through a tile recuperator causing a final mixture of combustion air at 1250 F.

The pit controls get their primary impulse from the radiation tube located in the wall opposite the burner. This impulse, relayed through the pyrometer to an air-loaded cylinder, governs the quantity of combustion air fed to the pit. The combustion air passing through the burner venturi sets up a differential carried to a hydraulic ratio controller. The ratio controller in turn proportions the gas fed to the pit. Linked with the ratio control is a temperature compensator, receiving its air loading from the combustion air temperature record-

Figure 2 — General view of the soaking pit installation at Ford Motor Co.'s Steel Div., Dearborn, Mich. All electrical and combustion control equipment are located on the balcony in the background. The ingot buggy and its track are shown in foreground.

Figure 3 — An ingot is drawn from one of the new soaking pits. Individual pit covers, of sprung-arch construction, were adopted because they could be rolled back toward the existing balcony.

Figure 4 — The combustion instrument control panel is located on the heating balcony with all equipment in one cubicle. All gas differentials and pressures are transmitted to the control panel by air pressure.

Figure 5 — All breakers and switchgear for operating the soaking pit covers and combustion air blowers, and the motor-generator set for the ingot buggy are located within the control house. Back of the panel are the individual gas flow control valves and hydraulic tanks.

ing controller. The ratio control can be reset pneumatically from the panel. All hydraulic controls may be set from automatic to manual positions by rotating an electrical switch so designated on the panel board.

All the control switches, pyrometers, meters and gauges for all five batteries are mounted on the outer wall of a 138-ft panel house. Within the control house, which is 12 ft deep, are housed all the breakers and switch gear for operating the pit covers and combustion air blowers. Back of the panel are located the individual gas flow control valves and the five hydraulic tanks with the regulators mounted on them. The motor-generator set for the ingot buggy is also located within the control house.

Space dictated the design of the hydraulic mounting. The mounting consists of one tank from which hydraulic fluid is pumped to the six regulators. The regulators drain back to the same tank. Of the six regulators, four are ratio controllers, one for each pit of a battery. The other two regulators control the gas and air pressure to the battery.

In case of gas failure or shortage, oil may be used as an alternate fuel. Individual heaters and the necessary temperature controls are located on the control balcony directly in line with the respective battery they are to serve. The flow of oil to each pit is transmitted pneumatically to the instrument panel and recorded by the same meter that records gas flow. The total oil flow to a battery is transmitted and integrated electrically by a meter also on the panel.

The first battery was put in operation in August, 1952. This battery, as well as the remaining batteries, went in operation with remarkably little trouble from the control standpoint. Since that time, we have experienced some metering and structural problems which we feel may be of interest to the industry. When the first battery was put in operation, the main collector tunnel flues were constructed with five inches of insulating flake and seven and one-half inches of semi-silica brick laid on the concrete mat. The concrete erupted, heaving the brickwork. The damage was temporarily repaired by leveling off the loose brick and throwing firecrete and aggregate over the surface.

Realizing that the damage was caused primarily by over temperature of the concrete mat, and the lack of sufficient venting, the structure was changed on the next battery which was nearing completion. A course of hard brick was laid on top of the concrete mat and then a $\frac{1}{8}$-in. steel plate was placed on top of these bricks. Five inches of vermiculite was put on top of the plate, and three inches of firecrete placed on top of the vermiculite. Three rows of first quality firebrick were placed on top of the firecrete. All the remaining batteries were constructed in this manner.

Coke was piled too high in one of the pits of the second battery and slag ran over the waste gas bridgewall. The slag cut the silica brick under the bridgewall arch. This brick was replaced with first quality firebrick.

It was found that our pits were not holding ratio. The ratio regulators were checked very carefully and found to be correct. Further study was made on the burner venturi and it was found that the impulse produced in the venturi did not follow a square root function. It was found that on the high flows we had considerable excess air, but at low flows we had combustible in some cases.

A test unit consisting of the burner air header and fan was set up and experiments run to determine the actual venturi characteristics. The tests were run on cold air and verified our original conclusions.

The next problem was how to overcome our trouble. Tests were run on our pits for weeks and relative data was collected and compared. It was found that the manual pneumatic ratio setting very closely paralleled the pneumatic output of the pyrometer when maintaining approximately ten per cent excess air in the pits. The ratio slider was connected in parallel to the combustion air flow controller. Thus, the ratio slider changed its position relative to the fuel flow on the pits.

A series of tests were run to determine if this system

would hold the ratio. It was found that the ratio was maintained relatively constant.

As of this writing, three batteries have been installed. Two more batteries will be in operation later. During the month of April, 1953, the twelve operating pits produced 12.3 tons per hour. The average time was three hours and thirteen minutes. The average fuel rate was 582,000 Btu per ton with the average load being 95 tons.

DISCUSSION

PRESENTED BY

DAVID D. COUSLEY, Assistant Superintendent, Utilities, Wheeling Steel Corp., Steubenville, Ohio.

W. H. DAILEY, JR., Surface Combustion Corp., Toledo, Ohio.

W. J. FORSYTH, Assistant Combustion Engineer, Jones and Laughlin Steel Corp., Pittsburgh, Pa.

FREDERICK R. PULLEN, Fuel Engineer, Bethlehem Steel Co., Johnstown, Pa.

B. D. BARNS, Supervisor, Fuel and Utilities Dept., Steel Div., Ford Motor Co., Dearborn, Mich.

David Cousley: This paper strikes a familiar chord to us at Wheeling Steel. Lack of space, which was quite a problem at the Ford plant in regards to the new soaking pits, has also been encountered in various installations and changes at our Steubenville North plant.

Then too, six new soaking pits, almost identical to the new Ford pits, have been placed in operation at our South works this summer.

Platinum thermocouples are used for the primary impulse for pit controls instead of radiation tubes, but other than this, the control system seems to be the same.

The problem of too much excess air at high gas flows has not been encountered. Ratios have been holding from low to high flows very satisfactorily to date.

At present our pits are set up for coke oven gas as the only fuel but natural gas could be used as a stand-by fuel. A carbon or soot build up has been noticed in the four cluster gas burner and we wonder if you have encountered the same thing.

A similar build-up has not been noticed in the burners in our North pits, which have one large gas pipe rather than four smaller pipes.

W. H. Dailey, Jr.: I believe that in either eight or twelve of the soaking pits in this job, we had complete early failure of all of the cast refractory in the burner blocks. At this time, we do not know why. It may have been poor application on our part, or maybe there was too much water in the mix, or there might have even been bad refractory. These burner blocks are apparent duplicates of approximately 250 others that are pretty well scattered throughout the country. I would say that from our own experience in use of cast refractory, that cast burner blocks, in general, have been very good. Each of these burner blocks uses about one ton of cast refractory in the dry condition, and they represent a pretty large unit piece. In most cases, and I would say probably 95 per cent of the cases, these cast blocks have been far superior to the older construction. In about five per cent of the installations though, the failure has been spectacular. Sometimes when they fail, the soaking pits cannot be taken out of production and by the time you can do something about it, the top blocks are gone, and in some cases the covers may be damaged and in every case the metal gas burner tubes will be severely damaged at least on the end.

This paper describes the results of a successful project and describes very well the main design features of the equipment and the operating results. It also covers very well the problems encountered in putting the equipment in operation as well as the solution of these problems. It touches, however, only very lightly on the main problems of this project which were the planning for the actual layout of the building, including the soaking pits and the auxiliary handling facilities, and the transportation system for delivering ingots from the open hearth, and for delivering the heated ingots to the rolling mill. All of these were extremely difficult problems and at times seemed almost impossible of solution. The Ford Motor Co. engineering and operating staffs are to be congratulated on their success in turning a group of potential liabilities into one of the most modern, flexible and economical soaking pit installations in the world.

In addition to their planning of the physical layout, their engineers and operating people did a remarkable job in construction. Due to the limited space available and the lack of railroad tracks, and since there was only access from one end of the building, all of the material including heavy structural steel and all refractory had to be carried the length of the building by means of the overhead cranes while at the same time maintaining operations of the existing soaking pits. This was further complicated by the necessity for the cranes to travel the length of the building to the existing shuttle cars to obtain ingots for charging into the pits. The operation was so well organized, however, that the actual construction work was completed in record time.

This work was carried out in three steps. First, a battery of very old low production regenerative pits was removed and a new battery of four modern large pits was installed in its place. As soon as the foundation work was completed for the first battery and as soon as actual construction of the battery of pits started, a second old battery was removed and foundation work started for a second new battery. It was necessary to put two new batteries in operation before additional old batteries could be demolished in order to maintain the necessary heating capacity. The next stage was demolition and installation of a single or third new battery. On completion of this battery, the capacity had increased sufficiently so that two old batteries could be demolished at one time, so that in the third and final step construction of two new batteries proceeded simultaneously. Each succeeding new battery was further away from the point of access to the building and as successive batteries went into operation, the difficulty of delivering materials over them by crane increased almost in geometric proportion to the number of batteries completed. However, the Ford Motor Co. crane operators and construction engineers became more expert as the job proceeded so that they maintained practically perfect coordination between their operations and the delivery of construction materials.

We also believe that the Ford people should be particularly complimented upon the general layout of their electrical and combustion controls. We have observed this in operation now for over a year and are very favorably impressed with it. The amount of electrical wiring is reduced and very much simplified and all parts are easily accessible although the installation requires much less floor space than is normally used. In addition the actual control board on which are mounted the manual operating stations and the temperature controllers is extremely simple. The use of a large unit type of hydraulic regulator stand with no external piping except the lines to the actual operating cylinders is also a marked advance. There is no leakage of hydraulic fluid, and there is much better access for inspection and adjustment of the automatic ratio control devices than we have had in the past.

As pointed out in the paper, these pits were constructed of natural silica stone and the waste gas downtakes were constructed of pure silica brick. The waste gas flues were lined with semi-silica brick. The top blocks (coping tile) were superduty Pennsylvania fireclay and the lower walls of the soaking pit from the bottom to about 2-ft above the top of the coke were of unburned metal cased chrome brick and chrome plastic. The sand used for the seals was a very carefully graded high purity silica sand from the Sharon conglomerate. This sand was carefully sized but was generally much coarser than normally encountered.

During a recent shut down of the soaking pits while changes were being made to the blooming mill, we had the opportunity to make a careful inspection of all of the refractory. This plant had had exceptionally careful operation of the pit crane so that there was very little mechanical damage to the side walls or to the top blocks. This inspection showed clearly that for this type of an operation with a substantial number of hot top ingots, the major factor in setting the length of the life for pit walls and also for the top blocks is the erosion by slag from the hot tops, when charged hot top up. While in no case was the erosion serious as yet in this installation, the fact that there was so very little mechanical damage made it possible, to see exactly what the early stages of erosion due to slag were like. For example, in some locations a very small amount of iron oxide had started to run down a semi-silica brick flue wall. The path at the start was about ½-in. wide and only ¼ to ½-in. deep, but as it ran down the wall, it evidently picked up silica or other materials and acquired a lower melting point and a very much lower viscosity so that the path narrowed to from ⅛ to ¼-in. wide but the depth increased to as much as 6-in. In some cases it almost looked as though the slot had been made with a saw. The silica stone is much more resistant to penetration by the slag and the fluidity of the slag apparently does not increase very much as it runs down small channels in the face of the stone. This may be due to the type of construction employed, using relatively thin stone of the order of 3 in. thick bedded in a high chrome mixture with a joint thickness of ¼ in. or more. Probably these joints effectively arrest any continuous cutting of channels through the face of the wall. The performance of the extra coarse Sharon conglomerate in the sand seals was outstanding, and possibly these coarser sands will give better service than the finer grades normally used. There is some cementing of the grains on the inner edge of the top blocks from the iron oxide vapor in the soaking pit atmosphere. However, due to the relatively large grains the cement is not very adherent and even the sand which has accumulated on the top blocks on the hot side for some time is easily broken loose.

The apparent air deficiency which the Ford fuel engineers found, and which they corrected by automatically readjusting the fuel-air ratio control as the fuel input changed, caused us to make a very thorough investigation of this phenomenon in this steel mill and in several other steel mills throughout the country. After running many tests with all avaliable fuels including coke oven gas, natural gas, fuel oil and blast furnace gas and in pits with coke bottoms and with dolomite bottoms, we found an air deficiency, as indicated by flue gas analysis at low firing rates, over and above what could be accounted for by metering devices in the ratio control. This condition was made more evident when firing coke oven gas and operating at very high temperatures, approaching the melting point of the scale on the ingots.

On the theory that it might be possibly explained by consumption of the air in scaling of the ingots, we made an investigation of the literature covering the subject. We found that a great deal of work had been done on this subject by W. E. Jominy, D. W. Murphy and others. This published data showed that the scaling rates encountered in normal soaking pit operation could very readily account for a considerable part of the apparent air deficiency.

We found that in general the worst offenders from the standpoint of scaling are those fuels containing sulphur. The next highest scaling constituent in the fuel is hydrogen. The fuel constituent causing minimum scaling is carbon monoxide (as in blast furnace gas). Both the published scaling rate data and our own field tests confirm that in pits firing blast furnace gas, there is little or no apparent air deficiency, that is, a constant air-fuel ratio may be held from maximum to minimum firing rate and the flue gas analysis will remain constant. Pits fired with natural gas which is usually free of sulphur exhibit some air consumption due to scaling of the steel, but it is relatively low and is consistent. The pits burning coke oven gas and particularly those operating above 2400 F show this apparent air deficiency to a greater or less degree. In some cases this deficiency is only about 10 per cent and in others it has reached as high as 40 per cent at the lowest holding rates.

We believe that the problem of rate of scaling warrants a much more thorough investigation than we have given it so far, and we believe that as part of the investigation the actual amount of scale formed under various conditions should be determined, preferably on full size ingots but at least on samples of steel inserted into soaking pits operating under various conditions.

W. J. Forsyth: Mr. Barns has given an interesting paper and the problems that he encountered in combustion control, structure and limitation of space can

be appreciated since similar problems were encountered at our Pittsburgh works, but my comments are confined only to instrumentation and combustion.

It is interesting to note that the combustion control system is a combination of electric, pneumatic and hydraulic controls, and the satisfactory solution of the metering problem by alteration of the control system, rather than redesign of the venturi, shows that it is versatile. Does the combination of three mediums of control increase maintenance costs and complicate your maintenance personnel training program? In your opinion, has the multiple tube gas burner aided materially in maintaining better fuel-air ratios?

Since the combustion air blowers supply air at a pressure of 56 ounces to the header, what is the regulated pressure to the individual pits and is it determined by the desired maximum fuel input?

Does the fuel input to the pits vary, as in our installation, due to a shortage of regulated air to the pits, resulting in insufficient fuel input at maximum flows, thus increasing heating time? With three pits firing at a maximum rate, it became necessary to reduce or shut off the air to the fourth pit until the other pits approached the point of reduced firing. Several tests were conducted which revealed the restriction was the result of an undersized jet or burner assembly. A larger jet was secured and at the time of installation, it was discovered that the venturi, at the outlet of the jet, had collapsed. The larger jet and a new venturi were installed, which improved conditions, but a shortage of air still exists. Since, by visual observation, the new venturi continues to remain intact, additional tests are being conducted in an effort to further improve this undesirable condition.

The installation of an additional fuel tube is required when fuel oil is used during emergencies. Have any difficulties been encountered in inserting the oil tube into the multiple tube gas burner, and then maintaining proper flame direction?

F. R. Pullen: Having recently completed an expansion program in which somewhat similar problems were encountered, we at Johnstown extend our congratulations to the engineering and operating personnel at the Ford Motor Co. To modernize and provide for increased capacity within existing mill and soaking pit areas taxes the ingenuity of engineers and operators to the utmost. It, of course, goes without saying that all of this must be done with a minimum of interruption to the normal operations of the departments involved.

The installation of one central control station for an entire group of soaking pits is, I believe, unique. While this should be especially advantageous to the operating crews, it undoubtedly adds a few new problems to those responsible for instrument and control maintenance.

The author in his paper failed to mention the principal fuel used on these pits. The use of 1250 F air preheat leads me to believe that it must be low Btu fuel. If this should not be true, what is the author's experience with the combination of rich fuel and high air preheat? Previous papers presented to this society have warned away from this combination.

Failure of the concrete beneath the main collector flues is interesting to us at Johnstown. Using construction somewhat similar to that at Ford we had no trouble in this particular area, but did experience a similar difficulty under the high temperature recuperators. We also attributed the eruption to excessive temperature with a possible reservation. There was some evidence of water beneath the foundation and there was the possibility that water seeping into the hot concrete caused the failure.

The inability to hold air-fuel ratio due to the inaccuracy of the venturi installed in the burner could be a serious condition. I believe we are using the same type of venturi as a measurement of combustion air flow. Having once calibrated our fuel-air ratio regulators we have experienced no problems in holding fuel-air ratio. I should be interested to know what type of a ratio pattern was obtained, and what explanation there is for the failure of the venturi to follow the conventional pattern.

At the time the author wrote his paper the operating data on these pits was probably somewhat limited. With additional data now available, he may wish to comment further on this subject. I would like to know more about the average time interval between finish pour and charging, the type and range of sizes of ingots used, types of steel, and any other operational data which may be available at this time.

B. D. Barns: With regards to Mr. Cousley's question concerning carbon formation on the ends of the burners, we have experienced the same type of formation. This normally occurs at low flows due to the cracking of the gas at the elevated temperatures. It has been our experience that this formation is not a hard crust. Rodding the burner very easily breaks the carbon loose. We have seen cases where perhaps three of the four burners were well coated and this has broken off when the covers were rolled back for charging. On the whole, although we do get carbon formation, it has not become a serious problem.

Mr. Forsyth has asked the question, "Does the combination of three mediums of control increase maintenance cost and complicate your maintenance personnel training program?"

We feel that our maintenance cost has not increased particularly as much as the same equipment is used throughout our mill and is interchangeable. For the same reason, our people are familiar with the equipment because it is used throughout the mill.

We have had experience only with the multiple tube burner so that we feel that we are not a judge. Most of our troubles with fuel-air ratio result from the fact that the venturi differentials do not follow a square root function.

The regulated air pressure to the battery is 20 in. H_2O. This pressure would govern the gas flow to the pits as in our pits the air is the primary medium to the fuel-ratio controller.

The fan capacity was designed to deliver well above the pit maximum requirements so that we have not been troubled by insufficient air.

With regards to Mr. Dailey's comments concerning the burner ports, it would be well to point out that because of the high preheat temperature (1200 F) and the high heating value of the gas (490 Btu), a high flame temperature results. This, undoubtedly, would contribute to some of our burner port troubles.

PROBLEMS IN DEVELOPING ALLOY STEELS FOR AIRCRAFT GAS TURBINES

By F. L. VER SNYDER
Thomson Laboratory
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Lynn, Mass.

. . . . development of new steels and alloys by the steelmaker for almost impossible requirements has been essential in the manufacture of new machinery and equipment . . . .

▲ NEVER before has man been able to propel an airplane so fast or so efficiently at various altitudes. It appears as though man, having already flown faster than the speed of sound, will very soon fly two and perhaps three times the speed of sound. All this is possible because of the jet engine. The principle of the jet engine is quite simple. Incoming air is compressed, mixed with a vaporized fuel, ignited and the expansion of the gases used to propel an aircraft. A schematic illustration of an engine and the air flow through the principle parts of this engine is shown in Figure 1. Although this engine is now obsolete, the general features and the air and hot gas flow pattern is typical of axial flow aircraft gas turbines.

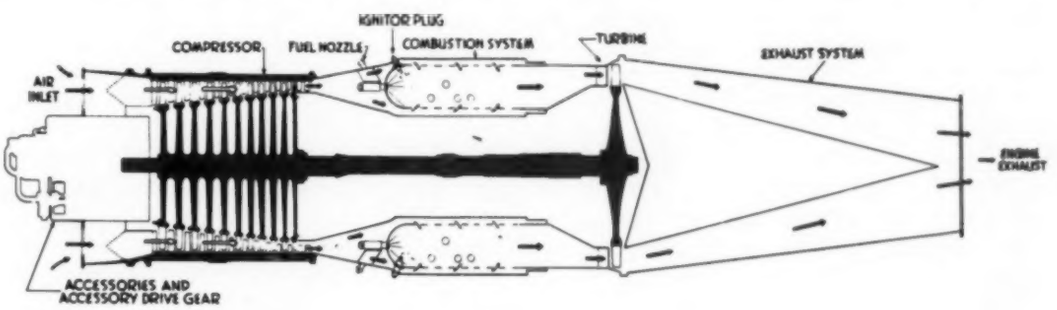


Figure 1—Section through gas turbine engine shows flow diagram.

As can be seen in Figure 1, incoming air passes around the auxiliary equipment into a multiple stage axial flow compressor, where it is compressed prior to entry into the combustion chambers. Here fuel in the form of vapor is mixed with the air and ignited by the means of an ignitor plug. The hot expanding gases pass through a nozzle diaphragm assembly, not shown, thence through the turbine wheel, which drives the compressor and auxiliary equipment, then out through the tail cone to provide thrust.

The air consumption in our company's newer J-47 engine with after-burner is approximately three tons per minute. The exhaust gases leave the exhaust nozzle of the after-burner at more than 1500 miles per hour.

The components of the jet engine operate up to approximately 1800 F. The following list is a break down of the temperatures encountered in the various components:

Compressor—Up to approximately 400 F.

Combustion liners—900 to 1500 F with an occasional opportunity for temperatures as high as 1800 F.

Nozzle diaphragm assembly—900 to 1650 F.

Turbine wheel—400 to 1200 F.

Turbine bucket—1200 to 1500 F.

Tail Cone—900 to 1400 F.

TIME — TEMPERATURE — STRESS

One can now begin to see why the jet engine metallurgist is quite "temperature conscious."

High stresses are combined with high temperatures in the following way:

1. In dynamic parts, as the result of high rotational speeds, alternating loads and thermal gradients.
2. In static parts, as a result primarily of thermal gradients and alternating loads.

It is obvious, therefore, that a metallurgist engaged in alloy development for aircraft gas turbines must consider not only the more usual properties, such as room temperature, ductility, tensile, yield and impact strengths, but also must concern himself with creep, rupture and high temperature fatigue strengths. In addition, he must also attempt to evaluate the effect of combined stresses, at various temperatures, on the alloy which he may develop.

The two most important high temperature properties that an alloy must be evaluated in these applications for, are rupture and fatigue strengths. For example, a jet engine turbine bucket is subjected to a combination of high temperatures and stresses only in a relatively small area. Therefore the portion of the bucket that is at these high temperatures and stresses will exhibit relatively large amounts of creep, but since this is distributed over a relatively small area, the total elongation of the entire bucket is small and the design clearances are not usually effected. In this case the problem becomes one of rupture in this highly stressed area.

Although there is continuous burning of the air fuel mixture in the combustion chambers, exciting forces are generated by the fixed number of chambers and diaphragm partitions through interruption of the hot gas discharge by these diaphragm partitions and the fixed number of rotating turbine buckets. This interruption of the hot gas stream causes alternating stresses in the components of the aft portion of the aircraft gas turbine. If the natural frequency of the operating part matches the frequency of the exciting forces, large stresses can be developed at relatively low energy levels.

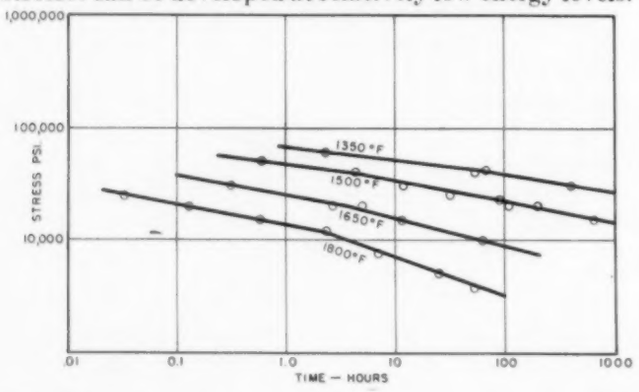


Figure 2 — Curves give constant temperature stress-rupture curves for S816 alloy.

Because of this ever-present possibility of resonant vibration, fatigue strength is a factor of considerable importance in the elevated temperature performance of many of the parts of the aircraft gas turbine.

One of the problems that has in the past constantly plagued the metallurgist engaged in the development of alloy steels for aircraft gas turbines was the need for evaluating his alloys, in terms of these complex operating conditions, by very time consuming tests. His

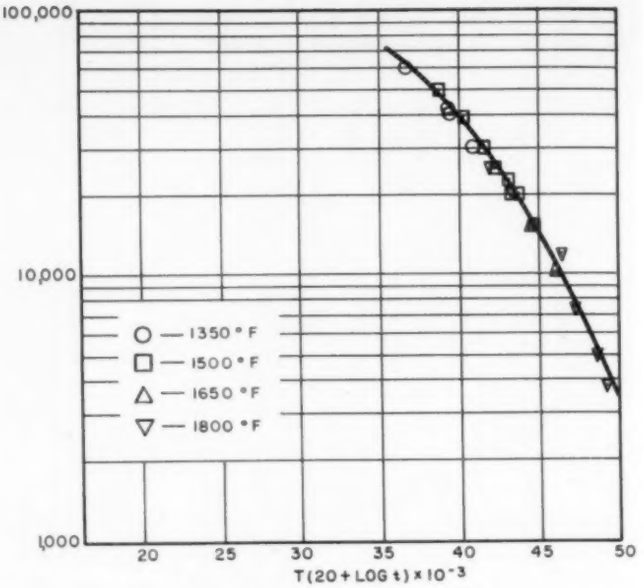


Figure 3 — The use of a master rupture curve gives simplicity and ease in obtaining all time-temperature-stress combinations. Curve is plotted for S816 alloy.

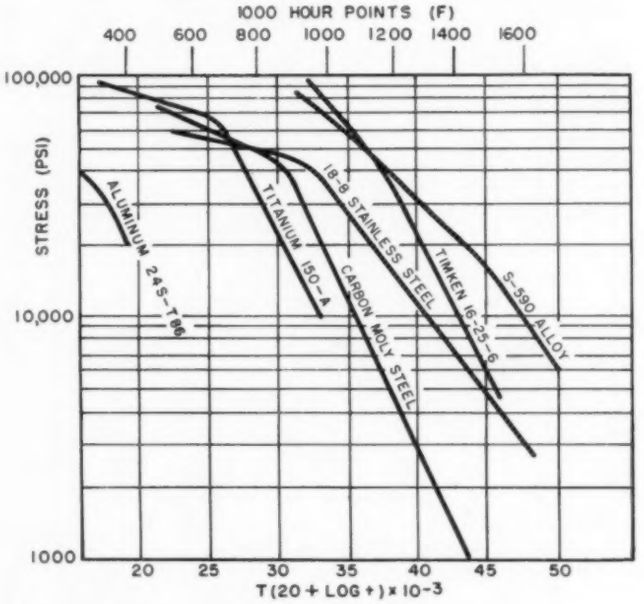


Figure 4 — Master rupture curves for alloys are given in this diagram.

prime need was for information concerning how long a given material would withstand various types of loading at some elevated temperature. Larson and Miller[1]* in developing their "Time-Temperature Relationship for Rupture and Creep Stresses," have greatly alleviated some of this difficulty.

Previous to the introduction of this relationship a series of constant temperature curves were needed to determine the rupture and creep properties of a single material (Figure 2). Each curve was then extrapolated to find the desired values of time and stress. Since straight line extrapolation could not be made, it was necessary to make extremely long time tests, sometimes lasting many months. The Larson-Miller parameter may be defined as $T(C + \log t)$ where T is the

*Numbers in parentheses refer to Bibliography at end of paper.

temperature in degrees Rankine, t is the time in hours and C is the material constant which has been determined as 20 for most materials. The value obtained from this expression is plotted as a function of stress and results in a simplified graphical stress-rupture presentation (Figure 3).

Using the Larson-Miller parameter, we are now able to plot all of our rupture data for several materials on one graph, eliminate the uncertainties of extrapolation and effectively swap time for temperature, thereby saving many hours of testing time.

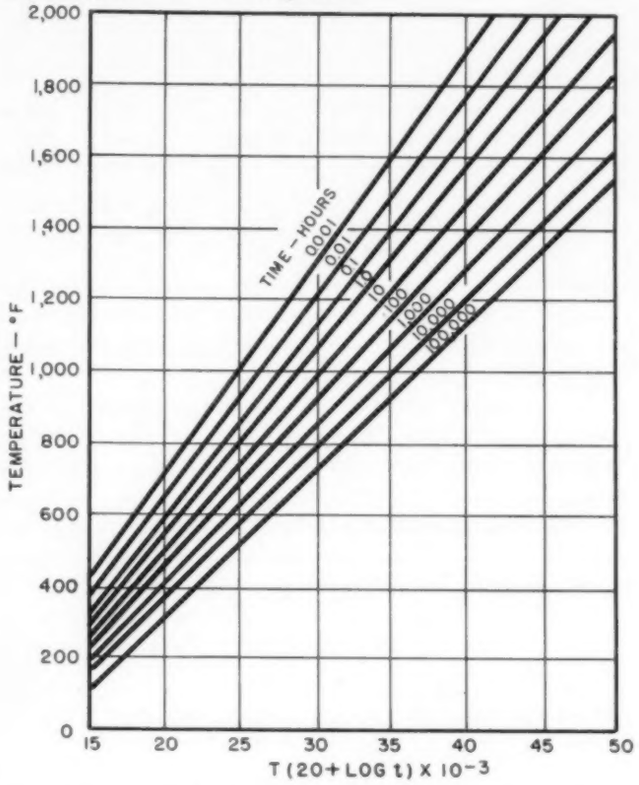


Figure 5 — Curves give temperature versus parameter T (20 + log t) for various times, where T is temperature in degrees, Rankine; and t is time in hours.

To illustrate, let us refer to Figure 4 where the master rupture curve for several materials have been plotted. We note that it is now quite easy to compare various materials at different time-temperature-stress conditions. Furthermore it may be seen from Figure 5 that

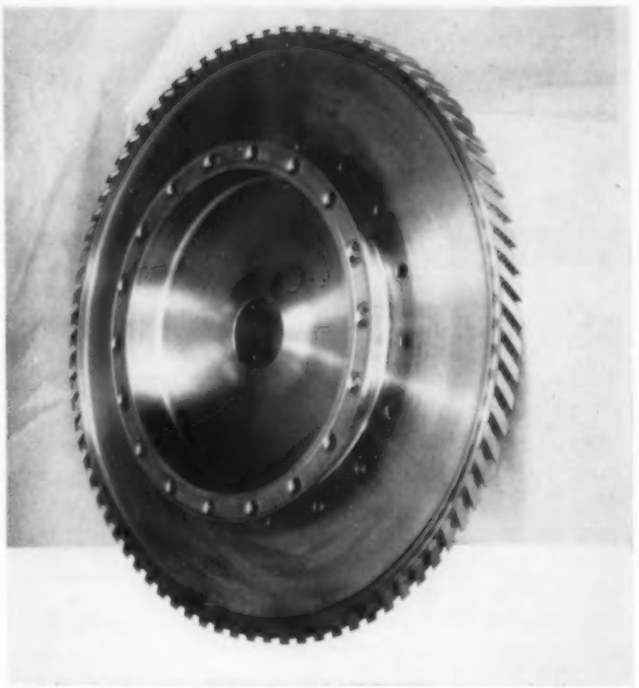


Figure 6 — In general, typical compressor wheels have used standard materials.

we may make a comparatively short time test of 17 hours at 1500 F and obtain stress data for 1000 hours at 1350F, since according to Larson and Miller's work these two time-temperature combinations should have equivalent rupture stresses.

Larson and Miller have shown that this relationship will be valid over the temperature range in which the high temperature metallurgist is most interested, with the exception of temperatures in the very narrow region of equilibrium phase boundaries. Tempering and overaging obey this relationship, and are therefore accounted for.

The development of this time-temperature parameter has been a singular factor in stepping up the development of high-temperature alloys.

Now let us examine the forward, mid-section and aft portions of the jet engine for typical examples of material developments. This division of the aircraft gas turbine into forward, mid-section and aft portion, is quite arbitrary and is used here only for convenience of presentation.

TABLE I

Nominal Chemical Composition in Weight, Per Cent

Alloy	C	Cr	Ni	Co	Mo	W	Cb	Ti	Fe	Other
AISI 4340	0.40	0.75	1.75	....	0.25	....	....	....	Bal	Cu — 0.14
AISI 403	0.10	12.0	....	....	....	....	....	....	Bal	Si — 0.5 max
AISI 310	0.08	25.0	20.0	....	....	....	....	....	Bal	....
AISI 321	0.06	17.5	10.0	....	....	....	....	0.50	Bal	....
AISI 347	0.06	18.0	11.0	....	....	....	1.0	....	Bal	....
29-9	0.12	29.0	9.0	....	....	....	....	....	....	Mn —1.50
HS 21	0.21	27.0	2.5	62.0	5.5	....	....	....	1.0	....
16-25-6	0.09	16.0	25.0	....	6.5	....	....	....	49.0	N_2 — 0.15
Inconel	0.05	14.5	78.0	....	....	....	....	....	6.5	Cu — 0.2
Nimonic 80	0.05	19.0	75.0	....	....	....	....	2.3	0.5	Al — 1.0
Waspalloy	0.08	19.0	Bal	13.0	2.5	....	....	2.5	3.5	Al — 1.0
M252	0.15	19.0	Bal	10.0	10.0	....	....	2.5	3.5	Al — 0.75
S816	0.37	20.0	20.0	43.0	4.0	4.0	4.0	....	3.0	....

FORWARD SECTION

In the forward portion of the jet engine we will concern ourselves with the multiple stage compressor assembly.

Compressor wheels (Figure 6) are largely a direct application of standard materials. Both aluminum alloys and a standard 12 Cr stainless steel (type 403) have been used in this application. The approximate chemical composition of all alloys specifically mentioned are listed in Table I. However, a new series of alloys may well be used in the very near future for compressor wheel applications. These alloys will be high strength titanium alloys used because of their more favorable strength to weight ratio.

Compressor blades (Figure 7) are manufactured from type 403 stainless steel. In view of its relatively low alloying content, just enough chromium to attain stainlessness, it has good corrosion and oxidation resistance which is essential for this application. Since this material is an air hardening grade of stainless, a minimum of distortion is encountered during heat treating to obtain the necessary mechanical properties. The high damping capacity of this material is also considered important in this application. In general the application of type 403 is direct and uncomplicated with one notable exception.

Early in the history of the processing of this material into compressor blades, considerable difficulty was encountered in the upset forging preparatory to blocking of the blade shape. These difficulties, mainly severe cracking during upsetting, were of sufficient magnitude to warrant metallurgical study.

On material received from different sources, which were given forging rating tests, it was found upon studying the microstructure that banded free ferrite was associated with the poor upsetting material. Examination of the chemistries revealed no important differences (Table II) so it seemed likely that the vendors' processing was largely accountable for the microstructural differences. Upon examining this material heat treated for 30 minutes and air cooled from temperatures between 1800 to 2300 F, it was found that the maximum free ferrite was developed at 2100 F, with very little below or above this temperature. Processing temperatures of 2200 F and above are not feasible because of the likelihood of, among other things, grain boundary fusion. However, processing temperatures of the order of 2000 F would seem reasonable. When these recommendations were carried out by the vendors, as evidenced by microstructural control testing for free ferrite of incoming material, further upset forging difficulties were eliminated.

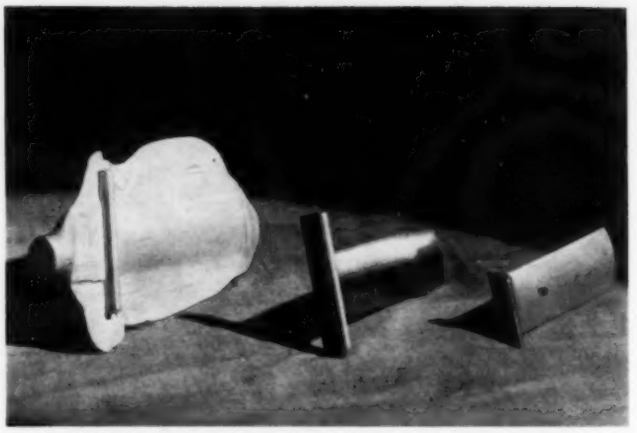


Figure 7 — Three stages in manufacture of a typical compressor blade are shown in this view.

The foregoing observations are the highlights of an extensive, thorough program which resulted in this empirical correlation between upset forging performance and microstructure.

Currently, with the proper metallurgical control, little difficulty is encountered in the processing of type 403 stainless to finished compressor blades.

MIDSECTION

Of most interest, metallurgically, in the central portion of the jet engine are the combustion chamber and nozzle diaphragm assembly.

The singular problem encountered in combustion chamber liners is distortion and buckling of portions of the liner which results in direct impingement of the flame on this liner segment with resulting failure. Improper burning conditions result in hot spots in the combustion chamber liner. These hot spots are the direct cause of high thermal stresses and gradients as well as the distortion which causes the liner to buckle into the flame passage.

TABLE II

Type 403 Stainless — Chemical Composition in Weight, Per Cent

Source	C	Cr	Mn	Ni	Si	P	S	Al	Sn	Cu	Mo
Vendor A	0.11	12.46	0.43	0.12	0.28	0.015	0.013	0.02	0.04	....	....
	0.10	12.42	0.44	0.13	0.32	0.014	0.012	Nil	0.028	....	....
Vendor B	0.11	12.04	0.43	0.12	0.38	0.019	0.016	0.02	0.02	....	....
	0.10	12.40	0.39	0.13	0.32	0.020	0.013	Nil	0.021	....	0.10
Vendor C	0.09	12.24	0.44	0.16	0.28	0.019	0.014	0.02	0.02	....	....
	0.10	12.65	0.40	0.21	0.39	0.015	0.019	Nil	0.021	....	....
Vendor D	0.11	12.42	0.43	0.13	0.31	0.015	0.028	....	....	....	....
	0.09	12.87	0.44	0.10	0.28	0.014	0.012	Nil	0.025	0.12	Nil
Vendor E	0.09	12.34	0.44	0.14	0.28	0.020	0.023	....	....	....	....
	0.07	12.60	0.36	0.11	0.48	0.014	0.015	Nil	0.024	0.13	Nil

Obviously then, one of the major considerations is design. A properly designed combustion chamber liner will cause the flame passage to be restricted to a relatively narrow cylinder, well away from the combustion chamber walls. If the design is such that the major portion of the flame passage remains well away from the combustion chamber liner wall, then the temperature, thermal gradients and thermal stresses in the combustion chamber liner will be relatively low. In such a case the average temperature would probably be of the order of 1500 F.

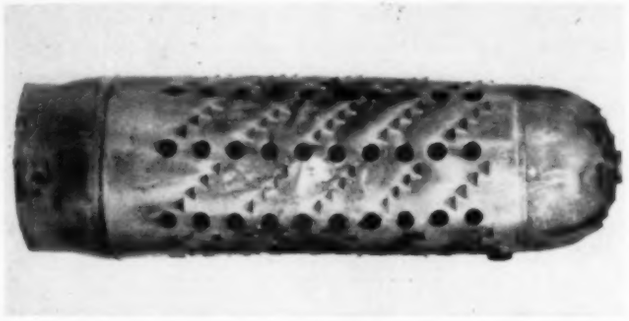


Figure 8 — A typical louvred combustion chamber liner is shown in this view.

With regards to material, Johnson[2] has pointed out that there exists a straight line relationship between tensile strength of the material of construction at 1800 F and the life of former designs of liners in component qualification cyclic endurance tests. He showed that HS 21 alloy, having the highest tensile strength at 1800 F had the longest life, whereas inconel and type 310 materials had both shorter lives and lower tensile strengths. For these former designs such a correlation was accurate and provided one with information which predicted material choice for this component.

However, with improved design, Figure 8, which amounted to incorporation of a relatively larger number of louvres in the combustion chamber liner, we find that not only will a material of lower tensile strength at 1800 F be adequate for this application but desirable, because of other material properties associated with the lower tensile strength, such as, high temperature ductility and cold formability. The need for having a large number of louvres brought with it this need for a formable material. This improved design involved the use of stainless type 310 material. Experience with this material and design revealed that residual cold work resulting from cold forming the type 310 stainless, caused a sharp reduction of the high temperature ductility. This led to premature failure at the louvre contour in the combustion chamber liner. Failure at the louvre contour often occurred within a few hours precipitating early failure of the entire liner.

Current designs of combustion chamber liners are manufactured from inconel. This material appears to maintain sufficient high temperature ductility after forming to prevent louver contour cracking. This material choice was also dictated by consideration of comparative oxidation scaling (Figure 9) resistance at 1800 F.

Reduction of the operating temperature of the material used in the manufacture of combustion chamber liners can also be brought about by using materials with increased thermal conductivity. With current designs one of the materials which may be used for this application is a stainless clad copper material. Taking advantage of the thermal conductivity of the copper core of this material, one can "even out" the thermal gradients along the length of the sheet, and thereby reduce the tendency for hot spots and localized failures. However, the inconel liners of current design seem to provide satisfactory service.

As the hot gases leave the combustion chambers, they next flow through the nozzle diaphragm assembly. This assembly is constructed of inner and outer bands of type 321 stainless steel, which have been punched to receive "blade shaped" HS 21 alloy partitions. These stationary partitions are welded into the inner and outer bands of the nozzle diaphragm assembly and are so designed as to properly direct the hot gases into the turbine buckets. The diaphragm partitions have received the most metallurgical attention, since they must withstand high temperatures and thermal cycling without warping or cracking. The present material, investment cast HS 21 alloy, is serving satisfactorily. However, a continuing search is in progress to develop new materials to increase the life of this component of the jet engine. Laboratory evaluation is conducted on the basis of cyclic thermal shock testing which shows good correlation with engine performance.

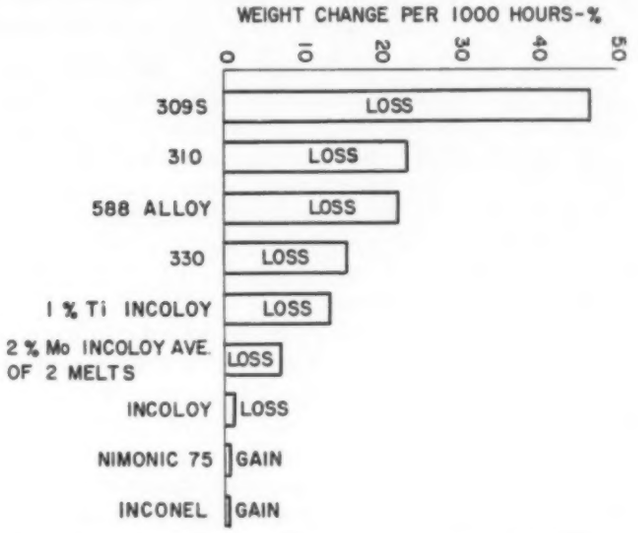


Figure 9 — Chart gives comparative scaling resistance at 1800 F in cyclic oxidation test of nickel-chromium alloys.

AFT SECTION

The portion of the jet engine which has required the most metallurgical attention has been the turbine rotor wheel assembly, with considerable emphasis on rim and bucket materials. In fact, from a high temperature alloy standpoint, wheel and bucket materials have long been given the most concerted metallurgical effort from the earliest days of the aircraft turbo-superchargers [3], [4], [5], since here is where the conditions of highest combined temperatures and stresses are encountered.

TABLE III

Average Rupture Properties of 16-25-6 Alloy

Condition	Temperature, F	Rupture strength, psi x 1000				Estimated elongation after fracture, per cent in 1 in.			
		10 hr	100 hr	500 hr	1000 hr	10 hr	100 hr	500 hr	1000 hr
Annealed 2150 F — 1 hr, A.C.	1200	55	43	34	31	....	12.5	19	16
Cold work Room temperature	1200	70	50	42	39	5	10	5	5
Cold work 1200 F — 22 per cent	1200	70	50	39	35	30	27	28	21
Annealed 2150 F — 1 hr, A.C.	1350	32	23	19	17	....	13	10	10
Cold work Room temperature	1350	39	28	22	20	20	14	7	5
Cold work 1200 F — 22 per cent	1350	36	24	18	16	24	20	20	20

Disc or wheel materials have been variously constructed of austenitic materials, ferritic materials and composite assemblies. Both the British and the Germans employ ferritic materials in their wheel discs because of lower operating temperatures resulting from sufficient cooling of the assembly. Our company uses a composite wheel, wherein the hub and shaft of the turbine rotor wheel assembly is constructed of AISI 4340 material and the rim material of 16-25-6 [6] alloy. In this case the austenitic rim is welded to the integrally forged ferritic hub and shaft using 29-9 weld wire. The advantages of this type of assembly as compared to the austenitic disc are lower overall alloying content and elimination of the problems of size effect encountered in large austenitic wheel forgings. In the evaluation of 16-25-6 alloy for wheel rim applications, approximately 10 different alloy compositions were forged and given high speed bursting tests. The average bursting speed and range of bursting speeds of these wheels were not substantially better than the 16-25-6 alloy. Cost, machinability and weldability were also factors which argued in favor of the 16-25-6 alloy.

With the 16-25-6 alloy processing problems, as well as some inherent material characteristics, have been the major concern of the engine manufacturer. Strict temperature control during the forging of the rim must be maintained to prevent loss of rupture ductility. In addition the alloy must be "hot-cold worked" to obtain the necessary room temperature yield strength and high temperature rupture strength [7], [8] for this application (Table III). The term "hot-cold worked" has been used in high temperature metallurgy for several years. It is used to differentiate elevated temperature (1200-1350 F) for cold working from room temperature cold working, although strictly speaking any mechanical working done below the recrystallization temperature of the material is defined as cold work. Since the first usage of 16-25-6 alloy for gas turbine wheel rim applications, much has been learned about the proper processing and needed metallurgical controls. However, with an increased understanding of the compositional and processing variables of the 16-25-6 alloy in the last few years, there has also been an increased severity of operating conditions which a wheel rim must withstand.

Certain operating conditions subject the rim material to cyclic quenching from the operating temperature at 1200 F to temperatures as low as –100 F. The need for considerable ductility and resistance to thermal cycling failure is certainly apparent. Some of the problems are being approached through new melting techniques such as an electric ingot continuous melting process. Another approach is the study of the metallurgy of the alloy and its constituents [9] in an attempt to understand and solve high and low temperature ductility problems.

Material development for gas turbine buckets can be conveniently divided into three classes according to alloy base elements: iron, cobalt and nickel. No iron base alloy has been developed to the present time which has sufficient strength up to 1500 F to warrant its consideration as a gas turbine bucket, although some effort has been expended in this direction. Outstanding alloys for this application have been developed in the cobalt base (S-816 alloy) and nickel base (nimonic, waspalloy and M252 alloys) materials. During the period of development of the currently used gas turbine bucket alloys, the object of the research and development was to most expeditiously arrive at these alloy compositions which would serve this application. Consequently much of the data available is of a practical nature, since fundamental data concerning the alloy systems themselves were of secondary importance.

The development of materials for these turbine buckets would not be adequately described without a word about processing. The choice of an alloy or variation of the composition of a given alloy will certainly be influenced by the final condition in which it is to be used, i.e., cast or wrought. To over-simplify somewhat, the current recognition of the superior high temperature fatigue strength of wrought alloys and the need for this magnitude of fatigue strength, due to current shroudless bucket designs, has dictated the choice of wrought alloys for most present day aircraft gas tur-

bine bucket materials. Consequently this discussion of gas turbine bucketing will confine itself to wrought alloys used in this application.

S-816 alloy was developed by Allegheny Ludlum Steel Corp. for service at temperatures in the range of 1200-1500 F. The major application of this alloy has been for gas turbine buckets operating at temperatures up to 1500 F.

The alloy is largely a solution hardening alloy. Although the hardness after a 1400-1500 F age has increased over the hardness of the 2150 F solution treated condition, the alloy cannot be considered an age hardening alloy in the classical sense. It is believed that this hardness increase is due to the non-coherent precipitation of carbide. This reaction hardens the alloy by reprecipitation of solutioned carbides in a finer, more dispersed form.

The primary minor constituent which has been identified in the microstructure by X-ray diffraction and metallographic techniques is columbium carbide [10]. When columbium is left out of the alloy the carbide Cr_7C_3 precipitates.

The mechanical properties of this alloy will be discussed in conjunction with alloy M252 and other nickel base titanium age hardenable alloys.

This alloy is processed into gas turbine buckets from 7/8-in. round bar stock by first upsetting the bucket slag and subsequently blanking the rough shape and finish forging to size. In order that this material may be successfully precision forged to the final bucket dimensions, it has been necessary in its processing to initiate several metallurgical controls. All incoming bar stock is given an upset forging rating test in order to determine the suitability of that particular heat or lot of material for subsequent processing. The top forging temperatures must be quite closely controlled in order to prevent undesirable duplex grain growth [11]. After surmounting the initial problems of the manufacture of gas turbine buckets from this alloy, it has given extremely satisfactory service.

In 1946, our research laboratory initiated a research project to satisfy the basic need for a systematic study of high temperature alloy properties in order to obtain fundamental relationships. It was anticipated that this research would result in principles which would form the basis for the prediction of high temperature properties and for the empirical design of high temperature alloys.

This project was designed primarily to study solid solution and precipitation hardening and their relationship to high temperature properties, although the effects of allotropic transitions were also studied in many of the alloys rich in iron or cobalt. Among other things, relationships between incongruous element additions and mechanical properties were outlined. Incongruous, here, has the meaning of large atomic size differences, large melting point differences and low solubility compared with iron, chromium, cobalt and nickel.

Through coordinated effort with this research by various laboratories of our company, several promising alloys were developed.

An alloy independently developed by the Thomson Laboratory was alloy M252*, a nickel base titanium age hardenable alloy. It was designed for operation at temperatures up to 1500 F. It is a precipitation hardening alloy in the classical sense.

In the solution treated condition, this alloy has a Rockwell C hardness of approximately 15. In the aged condition the material has a Rockwell C hardness of approximately 35. The aging curve as a function of temperature is shown in Figure 10. Examination of the microstructures of aged specimens reveals a grain boundary darkening during the initial aging followed by agglomeration of the precipitating phase during the latter stages of aging. After long time intervals at the aging temperature, general precipitation is noted throughout the entire structure. Identification of the phases present in this alloy indicates that the predominant minor phase is the complex carbide M_6C. In addition, titanium carbonitride inclusions and occasionally the carbide $M_{23}C_6$ have been observed. Even after long aging times no additional minor phases have been indicated by the techniques employed [9].

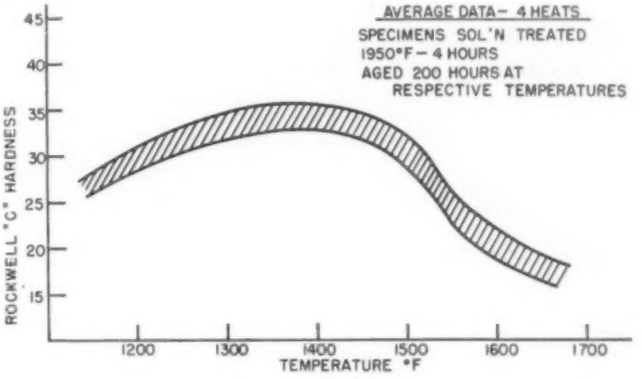


Figure 10 — Curves show how hardness varies with temperature for M252 alloy.

In the melting of most titanium containing alloys, special care must be taken with respect to the titanium addition. Some of the early laboratory heats of this alloy could not be forged. Examination of fractured surfaces of the ingots revealed a golden fracture appearance. Microstructural examination of these ingots revealed this phenomenon was due to the presence of the titanium carbonitride inclusions.

The British in their studies on the nimonic alloys and other producers of titanium containing materials have also observed the presence of the titanium carbonitride inclusions and have indicated the difficulties which the presence of this inclusion entails [12]. A rather thorough study of the titanium carbonitride and its effect on titanium containing materials has been made at the Thomson Laboratory [9]. It was determined that the presence of this inclusion, particularly when it was present in the form of chains or stringers, caused the serious early forging difficulties with this alloy. Some approaches to the solution of this problem have been to: (1). analyze the titanium master alloying addition for the presence of this inclusion and use only such master alloying additions as are completely uncontamin-

*Patent applied for

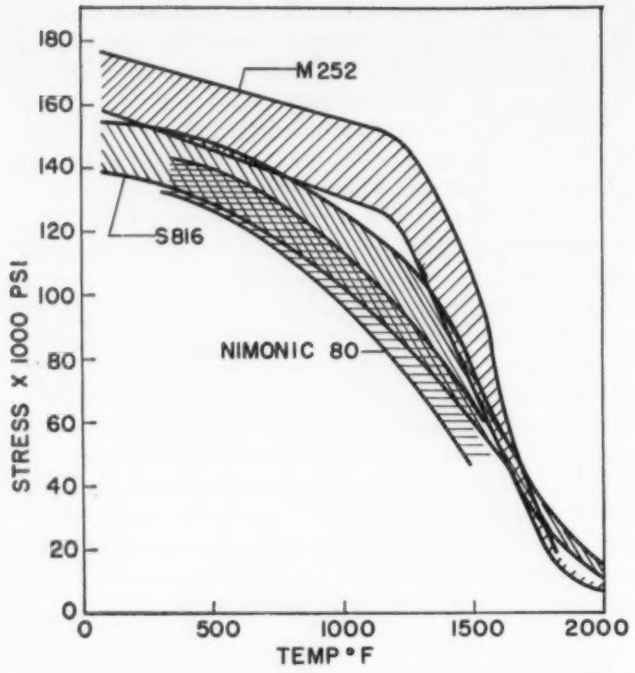


Figure 11 — Curves show variation in tensile strength with temperature for S816, M252 and nimonic 80 alloys.

ated, (2). observe special care in melting and pouring temperatures, and (3). the melt should be protected from the atmosphere both during melting and during pouring.

Since alloy S816 has become somewhat of a "standard" as a bucket material, it has become customary to compare other alloys, designed for applications up to 1500 F, to it. In the present case, comparison is not intended to register demerit for any of the alloys discussed, but rather to render an objective realization of the mechanical properties of the alloys at both high and room temperatures. Since both room temperature and high temperature tensile strength, and ductility measured by tensile test, is of importance in the turbine and bucket applications, Figure 11 illustrates some of these properties. Rupture properties of S816 compared to M252 (Figure 12) shows M252 to be somewhat stronger at the lower values of time and/or temperature while S816 becomes the stronger of the two alloys at the higher values. A marked difference in high temperature fatigue strength may be seen in favor of the M252 alloy, Figure 13.

From examining the properties presented of S816, M252 and the nimonic alloy, it is easy to see why these materials have been chosen for the turbine bucket application.

One of the production difficulties encountered with the titanium age hardenable nickel base bucket materials is oxidation during forging and heat treatment. The amount of scaling found on the surface of the bucket is not marked, however there usually is intergranular penetration of oxide to a depth of approximately 0.002 in. This same problem has been encountered by the British with their nimonic alloys [12]. The tendency of austentic materials to cold work has also added another complication to the production of turbine buckets from these kinds of materials. A surface layer of deformed metal is usually present as the result of bucket manufacturing technique. This results, upon subsequent engine operation, in a layer of recrystallized grains (Figure 14) which are considered to be extremely detrimental to the high temperature properties of the bucket. The rupture strength of these alloys is measurably decreased by the presence of both the intergranular oxide penetration and the recrystallized layer. Both the scaling problem and the cold work-recrystallization problem have been solved by electromachining of the finished blade. Currently, solutions for most production problems have been achieved and it is reasonable to expect that titanium age hardenable alloys will be used as turbine bucketing as copiously as other types of alloys have been in the past.

Figure 12 — Curves give rupture properties of alloys S816, M252 and nimonic 80.

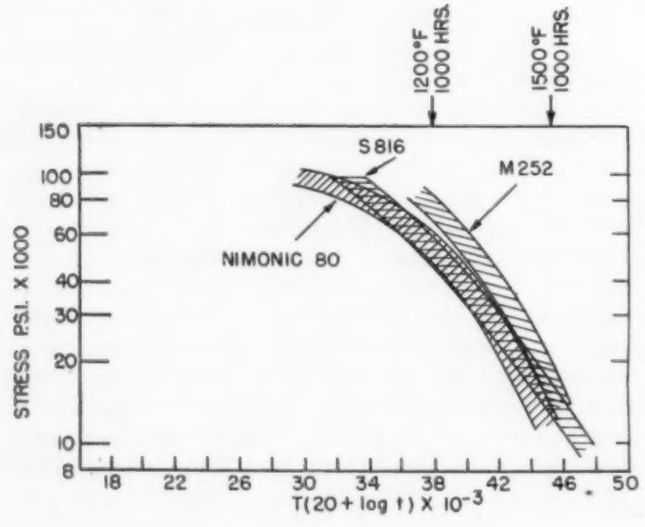
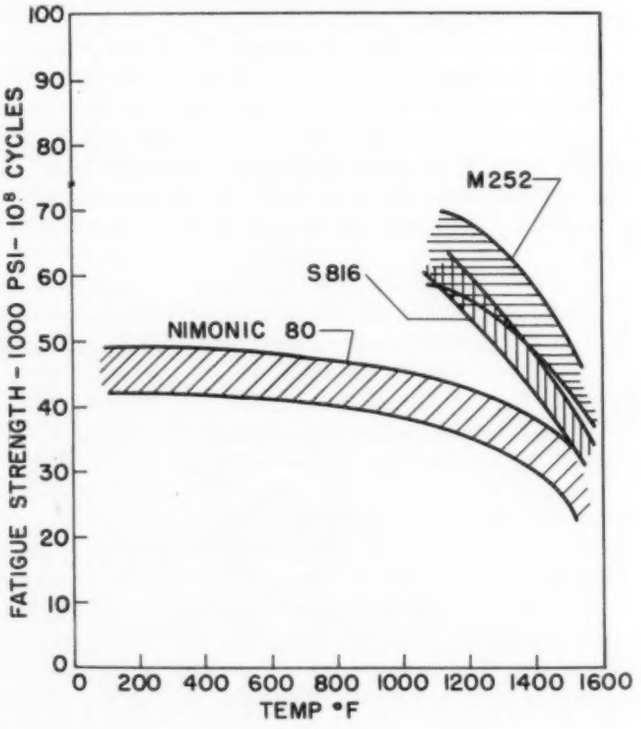


Figure 13 — Fatigue strengths are markedly reduced in the higher temperature ranges.



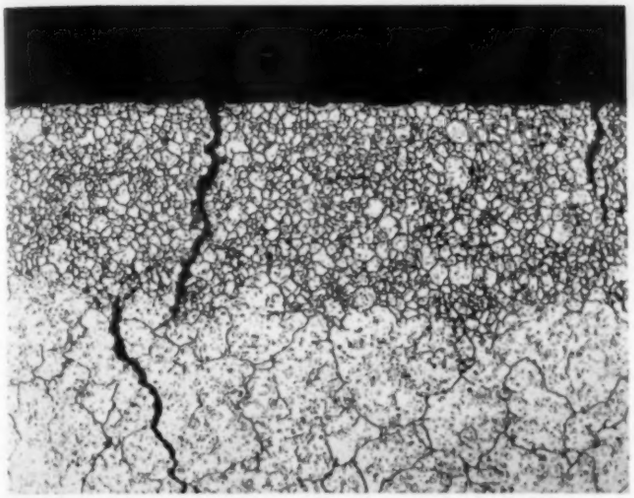


Figure 14 — Photomicrograph shows recrystallized layer on the edge of turbine bucket.

The jet pipe or tail cone of the jet engine which has been in the past made of welded type 347 stainless sheet material is currently being manufactured from type 321 stainless. Although the average operating temperatures in the tail pipe are of the order of 1200 F, "hot spots" may occasionally cause temperatures considerably higher. These "hot spots," which are the result of improper burning, cause high thermal gradients and stresses which may lead to premature failure. In general there have not been any severe material problems connected with this portion of the jet engine.

SUMMARY

The jet engine metallurgist never has the opportunity to feel self-satisfied, for though today's models and designs may be operating quite satisfactorily with the materials that he has either developed or recommended, he constantly feels the pressure of the future. Reduction of strategic alloying content, cost, lighter weight and other factors offer inspiring goals even with current designed machines. Looking to the future we see a constant desire for obtaining greater thrust and higher efficiencies. Each of these desires offers an interesting field of continued endeavor for the jet engine metallurgist. Soon perhaps, strictly metallic materials may not serve adequately for the applications which will be devised. J. H. Collins [13] in a graphical sketch of the progress, past, present and future in high temperature metals and ceramics indicated that the maximum temperature possible in service for metallic alloys would be approximately 2200 F. Above this temperature in the coming years we may have to rely largely on ceramets, ceramic oxides, nitrides, carbides and borides. So actually there is no conclusion to the development of materials for high temperature application.

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DISCUSSION

PRESENTED BY

EDWARD C. KELLER, Metallurgist, Simonds Saw and Steel Co., Lockport, N. Y.

EUGENE CANBY, Junior Engineer, Atlas Steels, Ltd., Welland, Ontario, Canada

F. L. VER SNYDER, Thomson Laboratory, General Electric Co., Lynn, Mass.

WARREN C. THIRY, Application Engineer, General Electric Co., Buffalo, N. Y.

Edward C. Keller: One of the most interesting things in the paper was the way in which the author showed how a modern laboratory can correlate and evaluate test data and so recommend a special alloy for a specific purpose.

Eugene Canby: Are cast buckets more suitable than forge buckets for use in aircraft gas turbines?

F. L. Ver Snyder: The decision to use either a cast or a forge bucket in the turbine rotor assembly depends on design. In general, forged buckets have a better fatigue strength than cast buckets. Therefore, in such engines as our J-47, the buckets used in the turbine rotor wheel assembly are forged S-816 buckets.

Warren Thiry: What happened to ceramics? We were supposed to have a solution to the problem of higher temperatures by coating steel with a ceramic.

F. L. Ver Snyder: Some success has been achieved in coating static parts with ceramic materials for high temperature service. In our experience we have been able to substitute lower alloyed steels, for example by coating stainless steels with ceramic as a substitution for super-alloys, and obtain equitable service life at temperature. I believe, however, that coatings for dynamic parts are still in the developmental stage.

AISE Fotorama....

ANNUAL SPRING CONFERENCE

PHILADELPHIA, PA.

MAY 3, 4, 5, 1954

The annual AISE Spring Conference, sponsored by the Rolling Mill Committee and held this year at Philadelphia's Bellevue-Stratford Hotel, drew a record 1005 registrants for the two-day affair.

At the Board of Directors dinner May 2, (1) board members, together with the AISE staff, take time out for the photographer. Registration (2) hit an all-time high as steelmen and suppliers converged on the Quaker City. J. D. O'Roark, Weirton Steel Co. (3) welcomes K. S. Kuka, Tata Iron and Steel Co., Jamshedpur, India, as the registrant traveling the farthest to attend the conference.

Authors and chairmen of the various technical sessions (4 through 10) check last-minute details before the program gets under way.

Enjoying a get-together between sessions (11) are Robert McMichael, Lukens Steel Co., C. W. MacDonald, Blaw-Knox Co., Ollie Britton, and A. H. Highley, Carpenter Steel Co. (seated), and J. M. Lewis and R. W. Frank of Blaw-Knox Co. (standing). Pictured in (12) are E. M. Benedict, U. S. Steel Corp., T. G. Simison, Kaiser Steel Corp., W. E. Boger, Alan Wood Steel Corp., and W. J. Wenger, Continental Foundry and Machine Co.

Elmer Lynch, Sheffield Steel Corp., (13) displays his cowboy boots with true Texas pride. In (14) Rudy Herbick, Reliance Electric and Engineering Co., points out an item of interest to Paul Thomas, U. S. Steel Corp., as Arnold Beyer, U. S. Steel Corp., and Jack Sutton, Sutton Engineering Co., look on. Shown in (15) are P. H. Wilson, and J. B. Sullivan, A. M. Byers Co., R. W. Leech, Westinghouse Electric Corp., George R. Roemer, Empire Steel Corp. and W. Dauberman, also of Westinghouse.

At the reception (16) which preceded the stag dinner E. L. Anderson, Bethlehem Steel Corp., and president of the AISE chats with M. W. Reed, U. S. Steel Corp., who was guest speaker, and James Farrington, founder of the Association. Also pictured at the reception (17) are F. W. Roebling, III of John Roebling's Sons (center) chatting with A. J. Berdis (left), general superintendent, Fairless Works, U. S. Steel Corp., and H. E. Warren, Jr., assistant general superintendent who were hosts for the inspection trip (18) May 5 to U. S. Steel's giant new installation at Fairless Hills, Pa.

Pictured in (19) are part of the more than 600 guests who attended the stag dinner.

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ADJUSTABLE VOLTAGE COAL BRIDGE INSTALLED AT STEEL COMPANY OF CANADA

By W. G. WRIGHT
Application Engineer
Canadian General Electric Co.

and

D. C. McCRADY
Electrical Superintendent
Steel Co. of Canada, Ltd.
Hamilton, Ontario, Canada

. . . . better performance was obtained through the use of adjustable voltage control . . . .

▲ EARLY in 1951 plans were being laid for an expansion program in basic iron and steel production to bring the Steel Company of Canada's Hamilton Works from 1,300,000 up to 1,900,000 ingot tons per year. The program included replacement of an old battery of coke ovens with a new 43-oven battery, addition of another 83-oven battery, a new 1500-ton per day blast furnace and a new four-furnace open hearth shop. One problem which faced designers immediately was that the existing combination ore and coal dock could not be expanded beyond the area required for this one program. Moreover, the dock was poorly situated, being at the far end of the plant from the blast furnaces and at right angles to the coke ovens. It was consequently decided to build a new dock at right angles to the old dock, to be situated parallel to the coke ovens. It would later be expanded at will out into the bay, an ultimate 5000 feet being contemplated.

The existing dock, 1500 feet long for both coal and ore storage, is served by three 12-ton man-trolley unloading bridges, operating from a 250-volt, d-c constant potential system. It was decided to purchase a 17-ton

TABLE I

	Old	New
Capacity of bucket, tons	12	17
Span center to center of rails, ft	375	375
Overall length, ft-in.	673-10⅜	690-1½
Height bucket over MWL masc., ft	60	62
Weight of bucket coal, lb	21,500	19,500
Weight of bucket ore, lb	22,000	25,000
Trolley weight (empty bucket), tons	80	120
Trolley speed, fpm	1000 at 795 motor rpm	1200 at 790 motor rpm
Type of hoist	2-drum — clutch	2 drum — individual motor
Trolley brakes	Air operated	Electric — shunt
Trolley motors	2-MC100 series	2-MDP618 shunt on 460 volts
Hoist brakes	Air type	WB50 (close), WB60 (hold)
Hoist motors	1-MC165 series	2-MDP618 shunt on 460 volts
Hoist speed, fpm	212	310
Acceleration rate, trolley, ft per sec	1.95 (avg to 90 per cent speed)	4.25
Bridge drive	2-MC60, 2-MC50 series	2-MD612, 2-MD610 shunt (pairs in series)
Bridge speed, fpm	75	90
Apron hoist	1-MC50 compound	1-MD610 series
Power supply	250-v, d-c constant potential	2300-v, 60-cycle mains
Main motor-generator set	—	1000 hp — 0.7 pf-2300-v, SM — N.R. starter air break contactors
Trolley generators	—	300 kw, 440-v shunt (in parallel)
Hoist generators	—	300 kw, 440-v shunt for hold and close and bridge motion
C/P exciter	—	50 kw, 250-v compound for control apron hoist, rail clamps
Low voltage power	—	550-v, 60-cycle, 3-phase, for rotating regulate set, turntable, blowers, etc. 115/230-v, 60-cycle for lighting

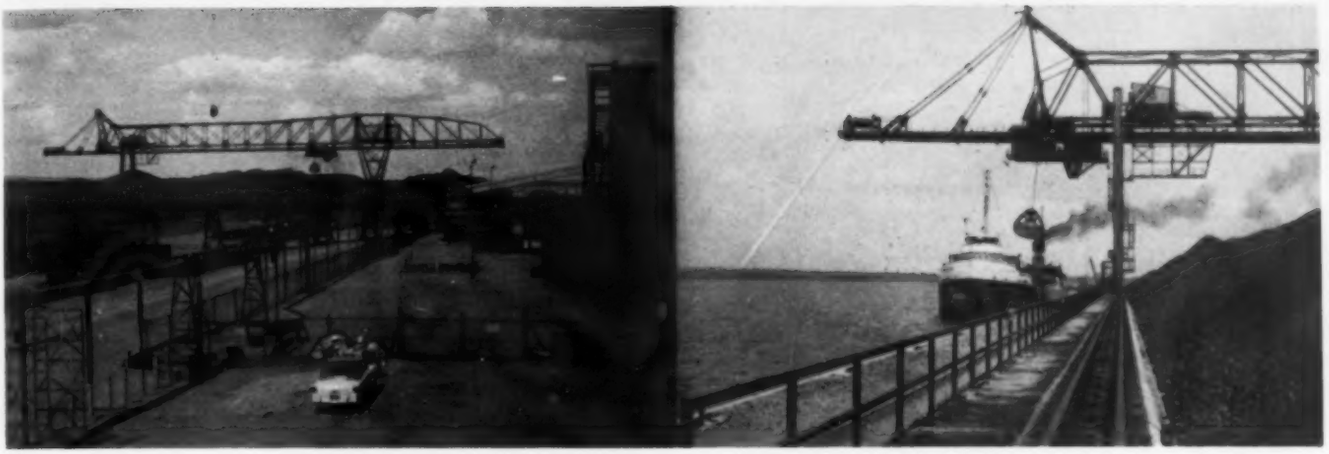


Figure 1 — Two general views of the 17-ton bridge are here shown.

bridge for the first section of new dock, and later move the old bridges over to the new runway, leaving the existing dock area available for mill buildings. Due to the voltage drop problems which would arise from the ultimate length of the new dock and the number of bridges which would one day operate along its runway, the decision was made to collect power at 2300 volt, 60 cycle. There appeared to be sufficient advantages in the adjustable voltage system, that the new bridge was purchased for this type of control. As far as cost was concerned, there was practically no difference, when conversion equipment was included. When the old bridges are moved, they will have to be either converted to adjustable voltage control, or conversion equipment will have to be located on each bridge. Table I gives the details of the old and new unloaders.

The first section of dock, about 1000 feet, to handle part of the coal supply for the 1952 season was built in 1951-52, ready in July 1952. The second section, 1500 feet, to handle additional coal for the new coke ovens and blast furnace, was completed in the spring of 1953. By 1955, the dock will be about 3500 feet long, when the old bridges will be moved.

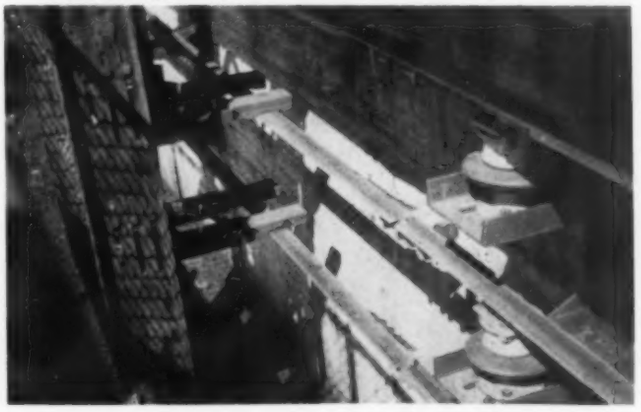
An interesting feature in connection with the new dock construction centered around the method of soil loading. This new area was almost entirely water prior to 1951, with loose silt, flue dust, and fine clay extending to 70 feet depth below the mean water level, where hard clay bottom suitable for loading, could be reached. The area was dredged free of the fine material, and slag gradually poured into the area to a height of 30 feet above water level. This process of preloading ensured that all loose material would be pushed out into the bay. Sheet piling was then driven in along the dock front, and the area beyond dredged to the proper depth for ship clearances. This construction has proven to be quite satisfactory, and obviated the alternative of expensive piling over the whole dock area.

The supply of power for the new dock was taken about 800 feet from a new 60-cycle substation using two 600-mcm, 5000-volt cables, one cable crossing the dock to feed each end of the new 1000-foot runway. Due to the bridge overhang, the collector rails had to be located at the shear leg end. The possibility of some dock settlement made it impossible to use regular underground duct work to carry these cables, and, as an alternative, each cable was laid in a wooden trough, and covered with a heavy concrete slab reinforced with old rails on top, thus precluding any possibility of the cable being touched by the bucket or by excavating machinery; yet the cable was free to move lengthwise to allow for settlement. Holes through the two runway piers give clearance for the moving cable. These cables were of special construction, paper insulated, lead sheathed, steel wire armored with jute covering plus double steel tape armor and jute overall. An outdoor enclosure housing a load-break disconnect is located at each cable terminal for connection to the collector rails. General views of the bridge are shown in Figure 1.

Aluminum collector rails were used, consisting of angles, flat side up, with shoes gravity overrunning. Figure 2 shows this arrangement, and also indicates the type of construction used for an expansion joint. The use of aluminum rather than steel plus paralleling cables was predicated on the reactance drops involved and overall economy. Shoes made of steel with zinc coating are used, the zinc simply being poured onto the steel surface in a temporary mold, and keyed by a number of holes in the steel shoe. The use of zinc prevents wear of the aluminum rails and cost of recasting the zinc is negligible.

The machinery house is located over the pier leg of the bridge, a view of the interior being shown in Figure 3. The house is provided with clean air from a blower and throw-away air filters. A small hand operated crane, and a hoisting winch located to make use of a

Figure 2 — Aluminum collector rails consist of angles with flat side up.



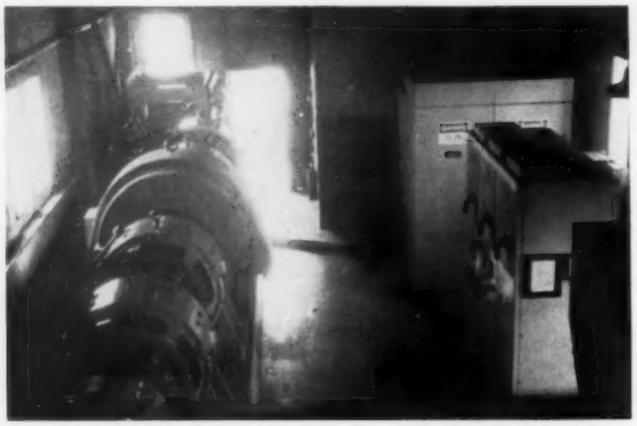


Figure 3 — Machinery house is provided with clean air from a blower which passes through a throw-away filter.

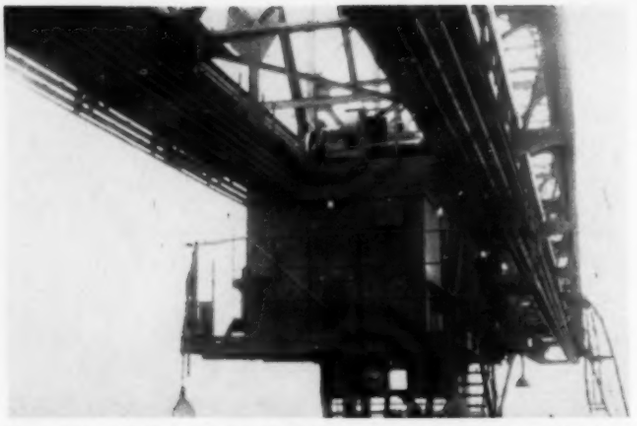


Figure 4 — The trolley collector system has eight collectors on each side of the bridge.

large hatchway are also included. Compressed air is available from a small compressor, for blowing out machines and so on. The trolley, when moved under the machinery house, can be nicely serviced through the floor hatchway. Load centers are provided for the 550-volt and 110/220-volt power supplies shown in the background of Figure 3, each protected on the high voltage side by current limiting fuse-disconnects.

A non-load break disconnect is located on the mounting platform at the shear leg, and a special neoprene jacketed type H cable carries the 2300-volt power up the shear leg and along the bridge to the machinery house. All other power wiring on the bridge consists of rubber covered wires and cables pulled in heavy rubber hose used as a conduit. This has been standard practice at the Steel Company of Canada for many years on all types of moveable structures, such as bridges, cranes, oven machines and so on, and has been found to give longer life and less trouble than rigid conduit, due to the effects of vibration and flexure which are always present.

In working out the adjustable voltage scheme which will be described later, it was decided to locate the main d-c controls and the rotating regulator set on the trolley. This meant bringing 550-volt, 3-phase power to the trolley, but as only one extra rail was involved, the advantages gained were worth this additional complication. In starting up the bridge, and for trouble shooting, it is an advantage to have this equipment on the trolley, and a great deal of time has been saved by this arrangement. The extra weight is not great, about 3000 lb for the motor-generator set and that part of the control that would otherwise be located in the machinery house. Moreover, the control rails carry the full generator field currents rather than the small rotating regulator field currents; with the latter scheme, bouncing of contacts or slight contact resistance would probably upset the regulating equipment and prevent the use of accurate and fast-acting regulating circuits. Some experimenting along this line was carried out on an existing crane in the plant, to determine the effect of sliding shoe contacts on a similar accurate regulating circuit, and it was on the basis of these tests that the decision was finalized to locate the regulators and control on the trolley.

The trolley collector system shown in Figure 4 uses 16 collectors, eight on each side of the bridge. To prevent troubles with possible grounds, each circuit was collected separately, with no common rails, a single exception being that all three generator field circuits were collected with a total of four rails. The original design of collector shoes and mounting arrangement was abandoned, as more vertical play had to be incorporated. Main power shoes are V-shaped, riding up underneath the inverted steel angle rails, and are made of bronze. Constant potential shoes are also V-shaped, but are made of cast iron. See Figure 5. All other shoes are made of bronze and ride up against the flat side of steel

Figure 5 — Constant potential shoes are made of cast iron and ride underneath inverted steel angles.

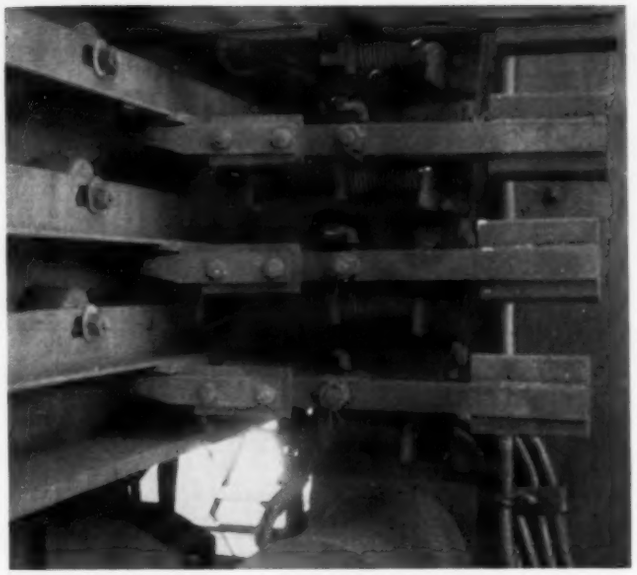


Figure 6 — Bronze shoes are also used which ride underneath flat side of steel angle rails.

angle rails, as shown in Figure 6. Cast iron shoes appeared to give unsatisfactory contact resistance for the generator field circuits. All shoes were lengthened considerably from the original design, being now about 12 in. long, to prevent bouncing at the apron hinge joint. All shoes are held up against the rails by combination gravity and spring tension.

ELECTRICAL EQUIPMENT

As described earlier, power is brought to the ore bridge at 2300 volts, 3-phase, 60-cycles. A general layout of the circuits is shown in Figure 7.

The main motor-generator set is located in the machinery house and is mounted on a self-supporting base with the various machines rated as follows:

4—300-kw, 440-volt, 1200-rpm, shunt-wound, d-c generators.

1—50-kw, 250/250-volt, compound-wound, d-c exciter.

1—1,000-hp, 1200-rpm, 0.7 power factor, 2300-volt, 3-phase, 60-cycle, synchronous motor.

Two of the 300-kw generators are used in parallel to feed the trolley motors. These generators are equipped with cross connected series fields for load sharing. The other two generators are used to supply the hold-and-close motors. In this instance the series fields are not used although they were supplied so that all four machines could be made duplicates.

The 50-kw machine is compound-wound, self-excited and is used to provide 250 volts constant potential for control and d-c auxiliaries such as rail clamps and apron hoist.

The synchronous motor is designed to have enough pullout torque to enable hold, close and trolley to hit maximum acceleration kw simultaneously. A reduced voltage starter employing current limiting fuses is used, but in cases of necessity the synchronous motor may be started full voltage.

Protection for this motor-generator set consists of circuit breakers for each d-c machine, bearing temperature relays, overspeed switch, and overvoltage relays.

Bucket control—The bucket is powered by two MDP-618 motors with 380 volts applied to the armatures. The adjustable voltage generators supplying these motors are controlled by rotating regulator regulators.

The control problem is to keep the bucket closed when hoisting a load and open when lowering empty. This has to be achieved at all times even while the bucket is accelerating and decelerating. This is obtained in the following manner:

Two three-point master switches are provided for control of hold and close. When these switches are both on the third point hoist, a load sharing circuit comes into effect causing the bucket load to be shared approximately equally between hold and close.

When the bucket is being lowered, a load relay in the close motor senses at the end of the accelerating period whether the bucket is empty or full. If full, the close motor will experience a surge of regenerative current. If empty, such a surge cannot take place. Hence to lower a full bucket the load sharing circuit is maintained. If, however, it is required to lower an empty bucket, a speed match between the two motors is obtained by regulating IR compensated motor voltages to be equal. The bucket then stays open even during the decelerating period when the tendency to close is greatest.

A further refinement which has been found to be useful is to provide a very light first point on the hold master switch. This is strong enough to hold the bucket upright on the ground but not strong enough to lift it. This provides a convenient way to take slack out of the hold line while digging takes place. This assists in obtaining a smooth get away.

Solenoid operated brakes are set in the off position under control of a voltage relay. This relay ensures that the motors have been decelerated to a low speed by regenerative braking before the brakes are applied. The brakes therefore are only used as holding brakes which greatly reduces wear. When starting, the brakes are released by a load relay which checks the presence of loop current before permitting release.

Emergency stop is by dynamic braking, with the cause of the emergency stop being recorded by glow light fault finders.

Trolley—The trolley is powered by two MDP-618 motors operating in parallel with 430 volts applied to the armatures. Load sharing is obtained by means of resistors in the armature circuit.

Control of the trolley is by two-point triggers attached to the hold and close master switch handles. The first point is a low speed of around 250 fpm and the second point is the top speed of 1200 fpm. In addition, two rheostats are mounted in the operator's cab. One of these enables the top speed of the trolley to be reduced down to 600 fpm, if required, and the other enables the current limit to be reduced from 4.25 feet per second squared down to 2.0 feet per second squared. These are used when the rails are wet.

Slowdown zones are provided at each end of travel. The first slowdown is permissive and operates if the speed of the trolley exceeds 300 fpm. Speed is checked by having a pilot generator geared to the trolley motors pick up a voltage relay. In spite of the fact that a relay

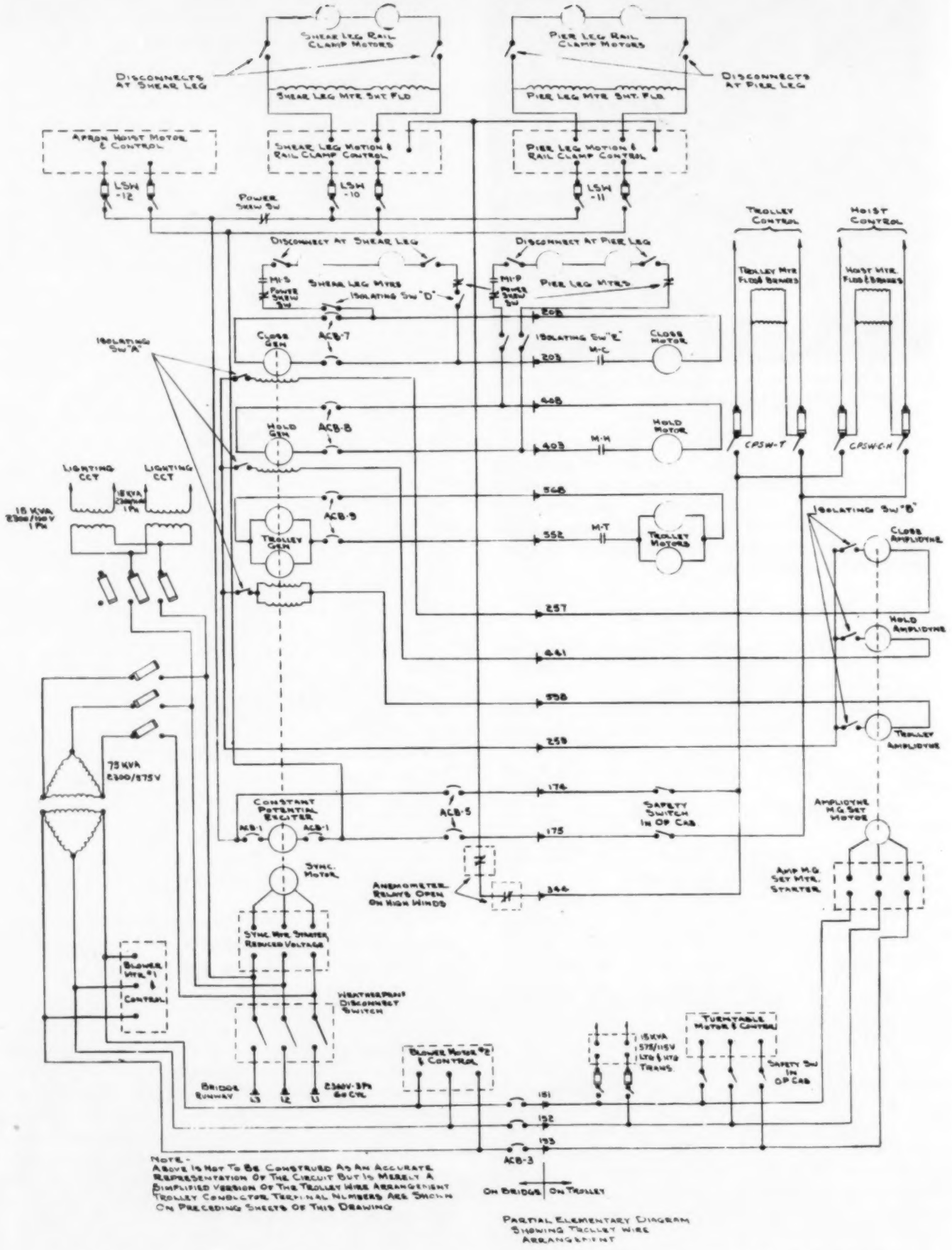


Figure 7 — Elementary diagram shows adjustable voltage, rotating regulator control for 17-ton ore bridge.

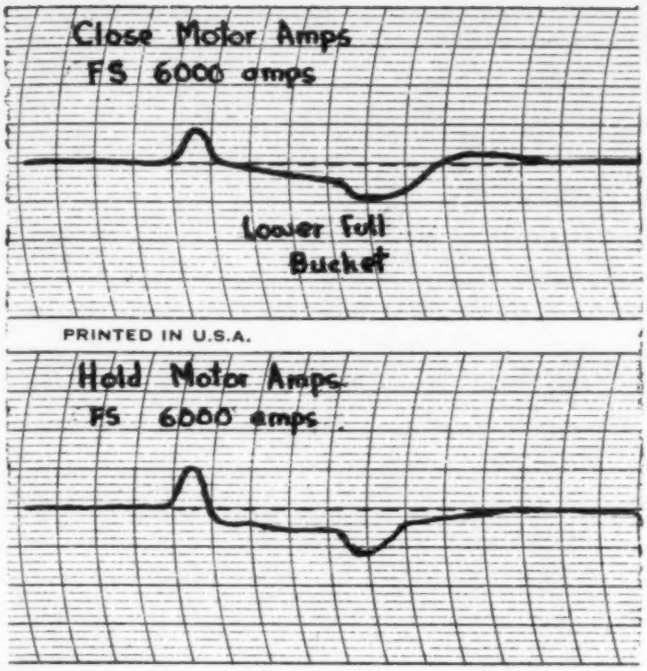


Figure 8 — Curve shows close and hold motor amperage when lowering full bucket.

has to pick up, great care was taken in designing this part of the circuit so that it fails safe in the event of any relay coil burning out. A second limit switch serves only to disconnect the motor from the line and enable the buffer to stop the trolley by itself. Due to the mechanical design of this buffer, it is essential that the trolley wheels do not skid. Hence at this point dynamic braking is not applied to the trolley, the only additional braking apart from the buffer itself being the solenoid brakes which are not enough to cause skidding. To backout the buffer a by-pass pushbutton is provided.

Bridge drive—Power for the bridge is taken from the hold and close generators. Thus the bucket cannot be

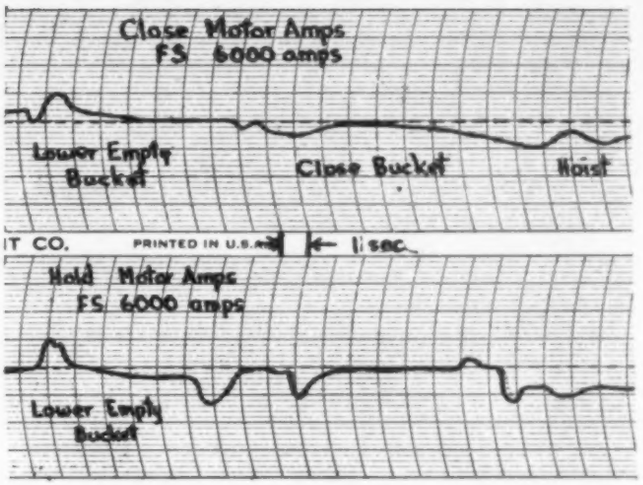


Figure 9 — Curve shows close and hold motor amperage for lowering of empty bucket, closing bucket and hoisting.

moved while bridging is taking place. When the operator presses a bridge transfer button in the cab, the hold and close motors are disconnected from their generators, the rail clamps are taken off and the bridge is ready to be moved. Control is by the hold and close master switches which now operate the bridge.

The time of build-up of generator voltage is controlled and a smooth acceleration is obtained. To obtain increased breakaway torque, the bridge motors are geared to run at some field weakening. Thus a full field start is used and field weakening initiated by a voltage relay.

No automatic skew control is provided. However, power limit switches are provided which shut the drives down if the bridge gets too far out of square.

Apron hoist—This is driven by a 65-hp series motor. The control is five-point magnetic in a standard crane circuit except that a gear type limit switch provides

Figure 10 — Curve shows current and voltage while trolley is accelerating.

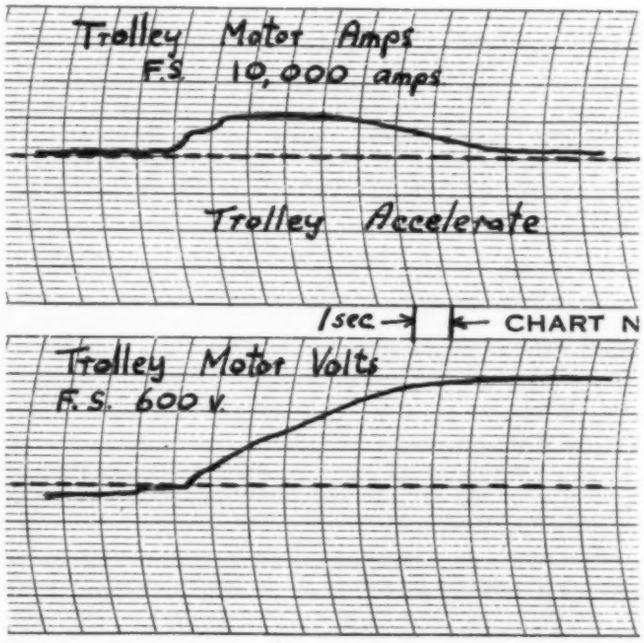
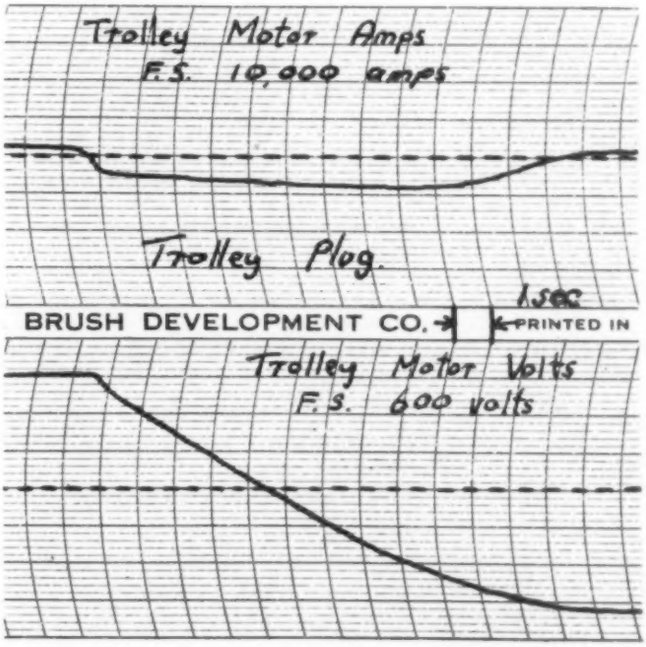


Figure 11 — Curve shows current and voltage while trolley is being plugged.



automatic slowdown and stop. Some consideration was given towards making the apron hoist adjustable voltage of the trolley generators. This idea was finally discarded on the grounds that it would use an extra trolley collector and would complicate the circuits unnecessarily.

Very little electrical trouble has been experienced. It is too soon as yet to assess the advantage of the adjustable voltage scheme as far as mechanical maintenance is concerned, but certainly there will be savings involved. The wear and tear on gears, bearings, bucket and cables is obviously less than with the old bridges, judging by sound and by observation. Electrically, maintenance is much lower, the collectors being the only source of regular maintenance work, as compared with the large amount of contactor and resistor maintenance on the old bridges. One great advantage of the adjustable voltage scheme is the rapid acceleration and retardation values achieved on both the hoisting and trolley motions, allowing far faster performance for the same size motors and for the same peak torque values.

The one 17-ton bridge has a free digging performance about the same as the other three 12-ton bridges put together—about 1300 net tons per hour, a fact not accounted for by the motor ratings involved nor the top speeds and bucket sizes involved. The overall boat dispatch time for the new bridge averages 35 per cent greater than that for the other three bridges together. This is of course accounted for during the clean-up, with three bridges available. From a power usage standpoint, tests have been run which indicate total kwhr per ton to be about 65 per cent of the power used on the old bridges—in both cases, power input to the generator sets being the power measured. (The old bridges operate from a pair of insulated d-c generator sets). However, as power costs are low (0.35 kwhr per ton unloaded) the savings are not great. Altogether, it appears at the moment that the advantages of the adjustable voltage scheme are as follows:

1. Lower mechanical maintenance due to smooth operation.
2. Use of far higher trolley and hoist acceleration rates. (4.25 vs 1.95 ft per sec per sec average for trolley).
3. Use of current limit control allows operator to set the rate of acceleration at the cab to suit wet rail conditions as far as skidding is concerned.
4. Much higher performance for the same sizes of motors due to non-peaking of the current during acceleration or deceleration.
5. Acceleration rates are far higher due to the fact that current limit or torque is held steadily for the entire period, whereas with the series motor, the first peak is limited by wheel slip, and a good deal of the acceleration takes place along the series characteristic at steadily lessening torque values.
6. Saving in power cost—about 35 per cent—although not great enough to influence the choice of control.
7. Greater operator comfort and less fatigue due to smooth operation.
8. Less trolley weight.

Generally it would appear that, when the old bridges are moved to the new dock, adjustable voltage control will be installed, to obtain the much higher performance, digging rate, and so on, thereby at some stage in the future obviating the necessity of purchasing a fifth unloading bridge.

By HAROLD I. HOWELL, System Project Engineer, Niagara Mohawk Power Corp., Buffalo, N. Y.

Power Generation Expansion

. . . . constant expansion in generating capacity must take place to meet the needs of industry . . . . developments in Northern New York have been the subject of national legislation and interest. . . .

▲ NIAGARA Mohawk Power Corp. is one of the largest electric and gas operating utilities in the United States. Approximately 85 per cent of the system's total operating revenues are obtained from the sale of electric power, and this paper will briefly discuss that phase of our business.

The company provides electric service in 36 of New York State's 62 counties. This service area extends from the Niagara Frontier in the west to the Hudson River Valley in the east, and from the state's northern border, Lake Ontario and the St. Lawrence River, to the foothills of the Catskill Mountains on the southeast and the Pennsylvania border on the southwest. It includes the important industrial areas of Buffalo, Lackawana, Niagara Falls, Syracuse, Massena, Utica, Schenectady, Albany and Watervliet. In this area of 21,000 square miles, the company provides electric service to about 973,000 customers and to a population of over 3,000,000.

The power requirements of these customers were in excess of 15,000,000,000 kwhr for the twelve months ended June 30, 1953. The power is produced by eighty-

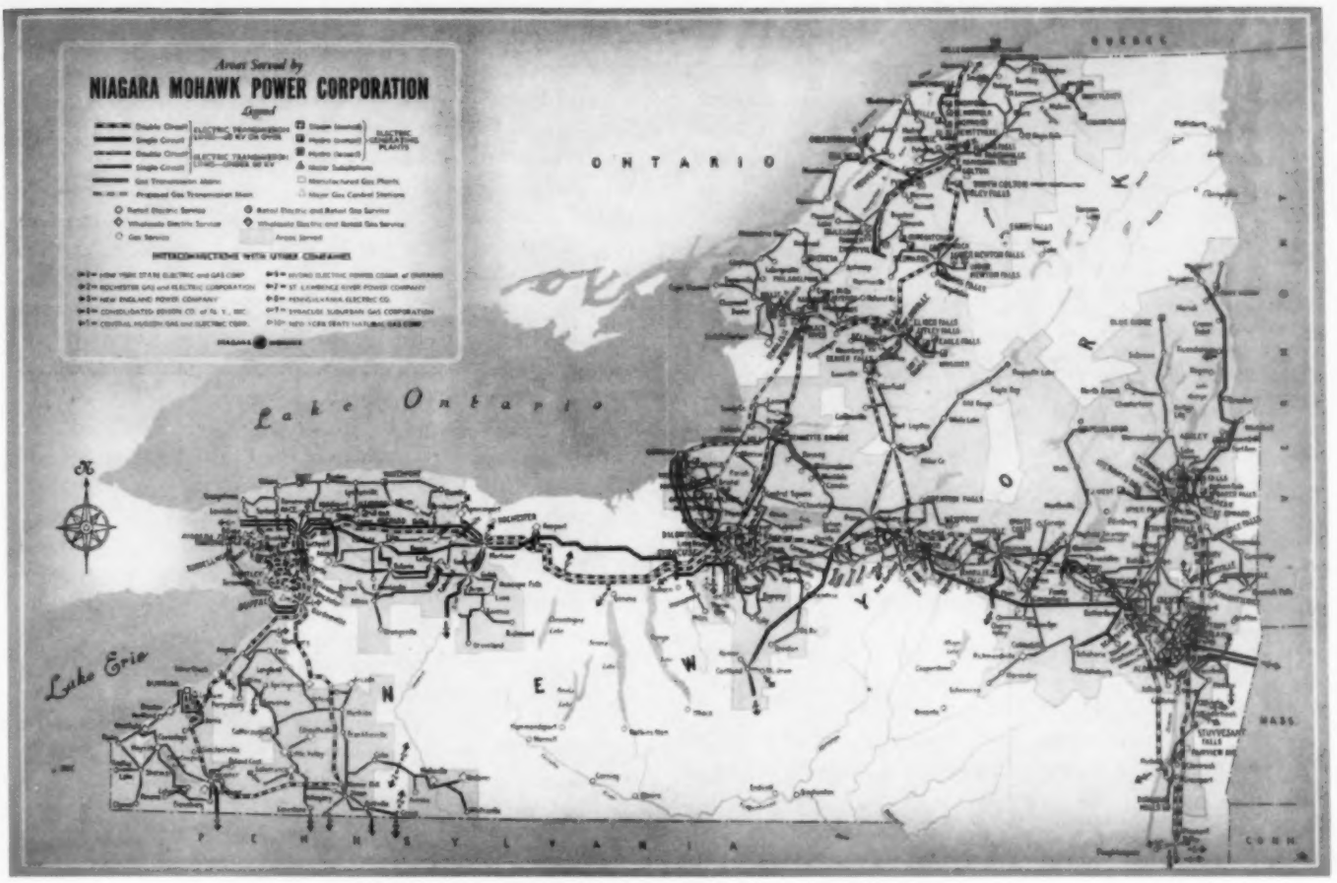


Figure 1 — Ties between power systems are a major factor in system economy.

six hydro-electric and seven steam electric generating stations. As of June 30, 1953, the rated generating capacity was made up as follows:

	Capacity in kw
Hydro stations (86 plants)	1,037,899
Steam stations (7 plants)	1,377,350
Purchased under contracts	107,000
Total	2,522,249

The total generation for the above 12-month period amounted to 16,793,000,000 kwhr.

The largest hydro plant is the Schoellkopf Station at Niagara Falls, N. Y. with a rated capacity of 334,800 kw. The largest steam-electric station is the Huntley Station at Buffalo with a present rated capacity of 625,000 kw. This capacity will be increased to 785,000 kw by the end of this year.

The transmission system of Niagara Mohawk is connected with such neighboring systems as Consolidated Edison of New York, Central Hudson Gas and Electric Corp., Rochester Gas and Electric Corp., New York State Electric and Gas Corp., New England Power Co., the Hydro-Electric Power Commission of Ontario and the Pennsylvania-New Jersey Power Pool. Because of these interconnections, Niagara Mohawk operates in a large northeastern power pool to the mutual advantage of each system allowing full economic use of all generating and transmission capacity.

The system's 3400 industrial customers use over 10,000,000,000 kwhr annually. These customers represent many basic and diversified types of industry and they produce an important part of the nation's manufactured goods.

Table I shows system industrial electric revenues by class of industry.

TABLE I

Industrial Electric Revenues by Industries

Six Months Ended June 30, 1953

Class of industry	Per cent of industrial electric revenues
Chemicals	14.9
Alloys and non-ferrous metal (except aluminum, magnesium and copper)	14.2
Aluminum and magnesium	13.6
Steel and iron	9.6
Paper and printing	7.1
Fabricated metal products	6.3
Electrical equipment	5.1
Automobile and transportation equipment	3.8
Cement, stone, clay and glass products	3.1
Textiles	2.8
Food products and ices	2.6
Brass and copper	2.3
Oils and lubricants	2.2
Abrasives	1.9
Airplane equipment	1.7
Flour mills and grain elevators	1.6
Mining and ore	1.6
Wood and fibre products	1.3
Rubber products	0.9
Gypsum	0.4
Leather	0.3
Miscellaneous and small unclassified	2.7
Total	100.0

Since 1948 the system electric sales of electric energy

have increased from 12 to over 15,000,000,000 kwhr at the end of June 1953, or more than a 25 per cent increase. To be able to supply these increased power requirements of our customers and to provide reserve generating capacity for use when it is necessary to take generating equipment out of service for maintenance, we have added the following generating units to our system since 1948:

Steam generating plants	Rated capacity — kw
Dunkirk — 2 units @ 80,000 kw	160,000
Oswego — 1 unit @ 80,000 kw	80,000
Albany — 2 units @ 80,000 kw	160,000

Hydro generating plants	Rated capacity — kw
Stewarts Bridge (Sacandaga River) — 1 unit @ 30,000 kw	30,000
	430,000

In addition to these plants, we completed in 1952 a storage reservoir on the Raquette River at Carry Falls with a storage capacity of 5,000,000,000 cu ft. This reservoir permits the storage of flood waters which would otherwise be lost for power production and has increased the firm capacity of existing down-river plants by about 8,000 kw. Downstream from Carry Falls we have plans to develop about 460 ft of head in five hydro plants which will add in excess of 100,000 kw of capacity by 1957. Two of these plants—South Colton and Five Falls—are now under construction and will be completed in 1954 and 1955, respectively. Construction on the other three plants will start soon.

We will also bring into service two 80,000-kw rated capacity steam units at our Huntley Station in Buffalo this winter, as well as one 80,000-kw unit at Albany. Next year, we will have completed the fourth 80,000-kw unit at Albany, which will increase this station to a rated capacity of 320,000-kw. All of the new steam units have a short-time overload capacity which permits an output of about 98,000-kw from an 80,000-kw rated capacity unit.

Thus, since 1948, we have either completed, have under construction, or in our design department 858,000-kw of rated generating capacity. This is about 280,000-kw more than the firm capacity of the American share of the proposed St. Lawrence power project. All of this design work is done by our system project engineering department in Buffalo. The company has spent about $250,000,000 since 1948 in enlarging its electric generating facilities and the associated transmission and distribution systems to meet the growing demands for power of its customers.

We also have preliminary designs developed for the construction of several hydro-electric plants on the Hudson, Black, Salmon and Moose Rivers and on West Canada Creek. We are also fortunate when the need arises in being able to add additional steam plants on Lakes Erie and Ontario, as well as on the Hudson and Niagara Rivers where an ample supply of cooling water is available. Many other electric utilities are not so fortunate in this respect. Some have to resort to underground wells and cooling towers for their supply of cooling water.

We now come to a brief discussion of our proposed 1,600,000-kw hydro development at Niagara Falls. The new treaty with Canada in 1950 permits the diversion of additional quantities of water in Canada and the United States for power development. Niagara Mohawk now has a license from the Federal Power Commission for the construction, operation and maintenance of our existing Schoellkopf and Adams generating stations at Niagara Falls, New York. Our engineers and operators have over a period of more than 50 years gained the engineering experience and know how to design, build and operate the proposed new Niagara project which will cost about $400,000,000 and we hope to obtain the license from the Federal Power Commission to proceed. It is estimated that about $23,000,000 a year in taxes will be paid to federal, state and local governments, if private enterprise is permitted to make the new development.

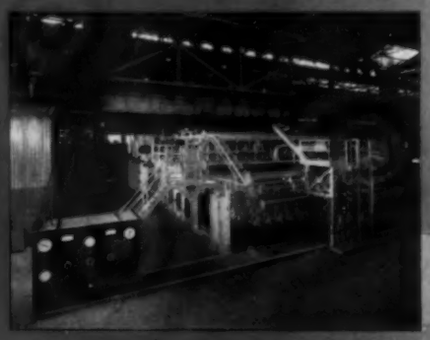
On July 9, 1953, the House of Representatives of the United States, by a vote of 262 to 120, passed and sent to the Senate the Miller-Dondero bill authorizing the Federal Power Commission to issue a license for private enterprise to develop an additional 1,600,000-kw of rated capacity of hydro-electric power at Niagara Falls. By a vote of 136 to 17, the House rejected a motion to substitute a bill which would have authorized the State of New York to construct and operate the development.

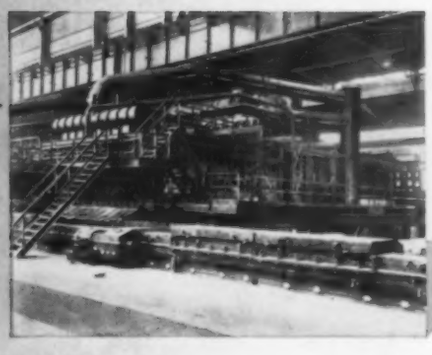
The private enterprise bill was awaiting action in the Senate when Congress adjourned this summer. It is co-sponsored in the Senate by Senator Martin of Pennsylvania, chairman of the Senate Public Works Committee, and Senator Capehart of Indiana.

Niagara Mohawk and four other New York State electric companies—Central Hudson Gas and Electric Corp., Consolidated Edison Co. of New York, Inc., New York State Electric and Gas Corp. and Rochester Gas and Electric Corp.—have proposed jointly to finance, construct and operate the development, under license from the Federal Power Commission, if the private enterprise bill is enacted. The companies have actively supported the bill and will continue to oppose government development of a power project which does not involve the exercise of any governmental functions such as flood control, navigation or irrigation. The five companies appeared before the Public Works Committees of both Senate and the House and demonstrated their ability to finance, design, construct and operate the development promptly without recourse to public funds.

Niagara Mohawk now owns the lands required for the project and over a period of more than 30 years its engineers have perfected the plans for the new development. We can start construction as soon as the license is issued and can complete the project in a shorter period of time and at a lesser cost than any other entity. This low-cost source of hydro-electric power will add about 8,000,000,000 kwhr a year to meet the electric power requirements of the users in the area. Rates for this power will be subject to the jurisdiction of the Public Service Commission of the State of New York, if the development is made by private enterprise. The project will also be under certain jurisdictional functions of the Federal Power Commission.

LOOK TO RUST FOR FURNACE EFFICIENCY





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You'll find, for example, that nickel UNIVAN steel castings . . . as compared with carbon steel castings . . . have greater resistance to firecracking and to torsional twist and shock.

And that applies also to peels, bearing covers, couplings and spindles, tongs and tong levers . . . all of them available in this special alloy steel.

We'll be glad to send you more complete information on UNIVAN castings. Or, to quote from your blueprints on your requirements . . . for castings in the rough or completely machined.

BLAW-KNOX COMPANY • • • UNION STEEL CASTINGS DIVISION
PITTSBURGH 1, PENNSYLVANIA

UNION PRODUCTS: charging boxes • peels • bearing covers • slag pots • tongs and tong levers • universal couplings and spindles • gears and pinions • ingot cars • charging box cars • special UNIVAN and ARMOR steel castings

BLAW-KNOX

NEW PROCESS DEVELOPED TO FORM METALS

▲ A revolutionary development in metal forming techniques, the Floturn process, has just been announced by The Lodge and Shipley Co., Cincinnati, Ohio lathe manufacturers. This newest metalworking process is fast, low-cost and saves costly critical material. Using a hardened and polished roller, the pressure is applied in a continuous spiral manner, gradually and accurately flowing a metal blank to the shape of a mandrel.

Conical, cylindrical, combinations of those two, and other complex shapes are easily formed. The process starts with a simple flat blank, machined blank, machined forging, drawn cup, wrapped and welded cylinder or a centrifugal casting. In many cases, with a single pass, the part can be produced directly to finished dimensions. In other cases, where extreme precision is necessary, 0.015 to 0.020 in. may be left for machining.

The new method differs basically from the centuries-old spinning method. In spinning, a blank considerably larger than the finished piece is used. Using moderate pressure, the blank is merely folded in a circular manner, using a hard tool against a round mold. This manual art requires a craftsman of considerable skill and experience. Parts produced may lack uniformity, and production may be low.

With the new process, the diameter of the blank is exactly that of the finished part, and thickness is heavier than required in the finished wall. The additional metal flows into the extended shape. The machine controls the operations; no particular skill is required of the operator. Pieces are uniform; dimensions can be held to ± 0.002 in. Production is high.

New alloys, including many considered hard to machine, are easily worked by the method. Among metals successfully formed are: all 300 and 400 series stainless steels, Timken 16-25-6 and 17-225, Haynes Multimet, Universal Cyclops Uniloy 19-9, inconel and inconel X, monel and K-monel, titanium T1-140-A, copper and aluminum as well as mild steel.

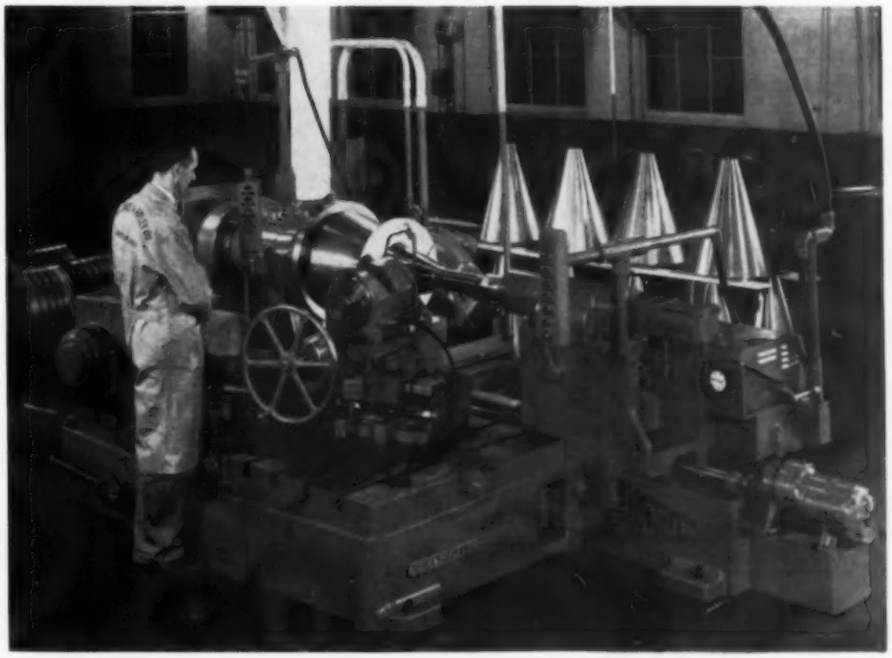
The No. 40 x 24 in. floturn lathe handles work 42 in. in diameter and 24 in. long. The No. 40 x 50 in. lathe handles work 42 in. in diameter and 50 in. long. Work of larger dimensions may be worked on special equipment. Blanks of the harder metals may be worked up to $\frac{5}{16}$ in. in thickness. Those of the softer metals may be worked up to $\frac{1}{2}$ in. in thickness.

The method actually increases the strength and hardness of the metal worked, and has a beneficial effect similar to cold rolling on the granular structure of the metal.

Illustrating savings in material alone, the following comparison of a part produced by forging and machining vs a part produced by the method are cited:

A finished workpiece weighing 50 lb, started as a forging with a weight of 369 lb. The forging cost approximately $276.75. For the same finished part, the floturn blank weighs 65 lb, costs only $48.75. The savings in material alone are $228.00 or 82½ per cent.

Figure 1 — Floturn lathe forms an exhaust cone for jet aircraft engine. Note the finished cones in the background.



Now!...

An INTERRUPTING RATING in EXCESS of 100,000 AMPERES *for every set of fuse clips in your plant* . . . simply by installing FUSETRON *dual-element* FUSES

The Biggest Electrical Protection NEWS Since BUSS invented the FUSETRON Dual-Element FUSE

FUSETRON is a trademark of the Bussmann Mfg. Co., Division of McGraw Electric Co.

In 1947 tests made by the Electrical Testing Laboratories of New York, showed that on a circuit set to deliver 50,000 amperes, FUSETRON fuses in all tests cleared the circuit safely.

50,000 amp. Interrupting Capacity in 1947
becomes
100,000 amp. Interrupting Capacity Today

After years of intensive development work on FUSETRON fuses new tests were conducted under conditions that simulated the most severe field conditions and these tests were witnessed and verified by the Electrical Testing Laboratories of New York.

On circuits set to deliver in excess of 100,000 amperes, 30 to 600 ampere, 250 and 600 volt FUSETRON dual-element Fuses on each and every test cleared the circuit without belching flame or venting hot gases and with comparatively little noise.

Oscillograms of these tests interpreted by the Electrical Testing Laboratories, showed that the total available amperes including the direct current component, reached values as great as 165,000 peak amperes on 240 volt tests and as high as 212,000 peak amperes on the 535 volt tests.

This indicates that an interrupting rating of 100,000 amperes for FUSETRON dual-element fuses is a conservative one.

No interference with time-lag

In the development work to increase interrupting capacity in FUSETRON fuses it was kept in mind that the time-current characteristic must be maintained. Time-lag is of utmost importance to give proper motor and electrical protection and to eliminate needless blowing of fuses.

Remarkable results have been achieved. Interrupting capacity has been greatly increased while the time-current characteristic of FUSETRON fuses has in no way been disturbed.

Play Safe - install Fusetron Fuses throughout the entire electrical system!

Think!...

ALL THIS ADDED SAFETY *without changing a panelboard or switch... plus* 10 Point Protection of FUSETRON *dual-element* FUSES!

Maximum Safety

With FUSETRON Fuses there is no cascading of interrupting rating — no places where an excessive fault current might cause serious damage. Every FUSETRON fuse has an interrupting rating in excess of 100,000 amperes.

You don't have to worry about selecting chosen spots in which to *pay extra* for "safe" equipment. Wherever a FUSETRON fuse is installed you have safety as sure and dependable as you can buy — no matter what you pay.

No Maintenance Costs

When FUSETRON fuses have once been installed properly you can forget about them. They need no periodic inspections to see if they will operate safely.

Dust, fumes, corrosion or age cannot prevent a FUSETRON fuse from opening safely. There are no hinges, pivots or contacts to stick or slow down the operation of the fuse on short-circuit.

With FUSETRON fuses — you get safety — without one cent spent for inspection or maintenance costs.

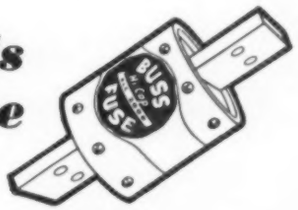
No Recalibration Costs

When a FUSETRON fuse does blow, there is no recalibration needed. As quickly as the fault in the circuit is corrected, you slip in a new fuse that has been CALIBRATED AT THE FACTORY BY ENGINEERS— a fuse that is as safe and dependable as the one that blew.

PLUS 10 POINT Protection with FUSETRON dual-element FUSES

1 Protect against short-circuits. **2** Protect against needless blows caused by harmless overloads. **3** Protect against needless blows caused by excessive heating — lesser resistance results in cooler operation. **4** Provide thermal protection — for panels and switches against damage from heating due to poor contact. **5** Protect motors against burnout from overloading. **6** Protect motors against burnout due to single phasing. **7** Give DOUBLE burnout protection to large motors — without extra cost. **8** Make protection of small motors simple and inexpensive. **9** Protect against waste of space and money — permit use of proper size switches and panels. **10** Protect coils, transformers and solenoids against burnout.

for SAFE PROTECTION on loads above 600 and up to 5000 Ampere install BUSS Hi-Cap FUSES



Tests have shown that BUSS Hi-Cap fuses have unlimited interrupting capacity on circuits of 600 volts or less.

They are designed to give protection against dangerous overloads as well as high fault currents — yet their speed of operation on heavy shorts limits currents to safe values. This minimizes damage to equipment and cuts down dangerous stresses on transformers.

When coordinated properly with FUSETRON dual-element fuses they will not open ahead of the fuses nearest to the fault. Thus trouble is isolated to the part of the circuit in which the fault occurs.

Added SAFETY on Old Installations

On installations where the increase in the capacity of the circuit has outgrown the interrupting rating of the circuit breakers, BUSS Hi-Cap fuses offer a safe and relatively inexpensive way to protect inadequate breakers against rupture in event of a bad fault.

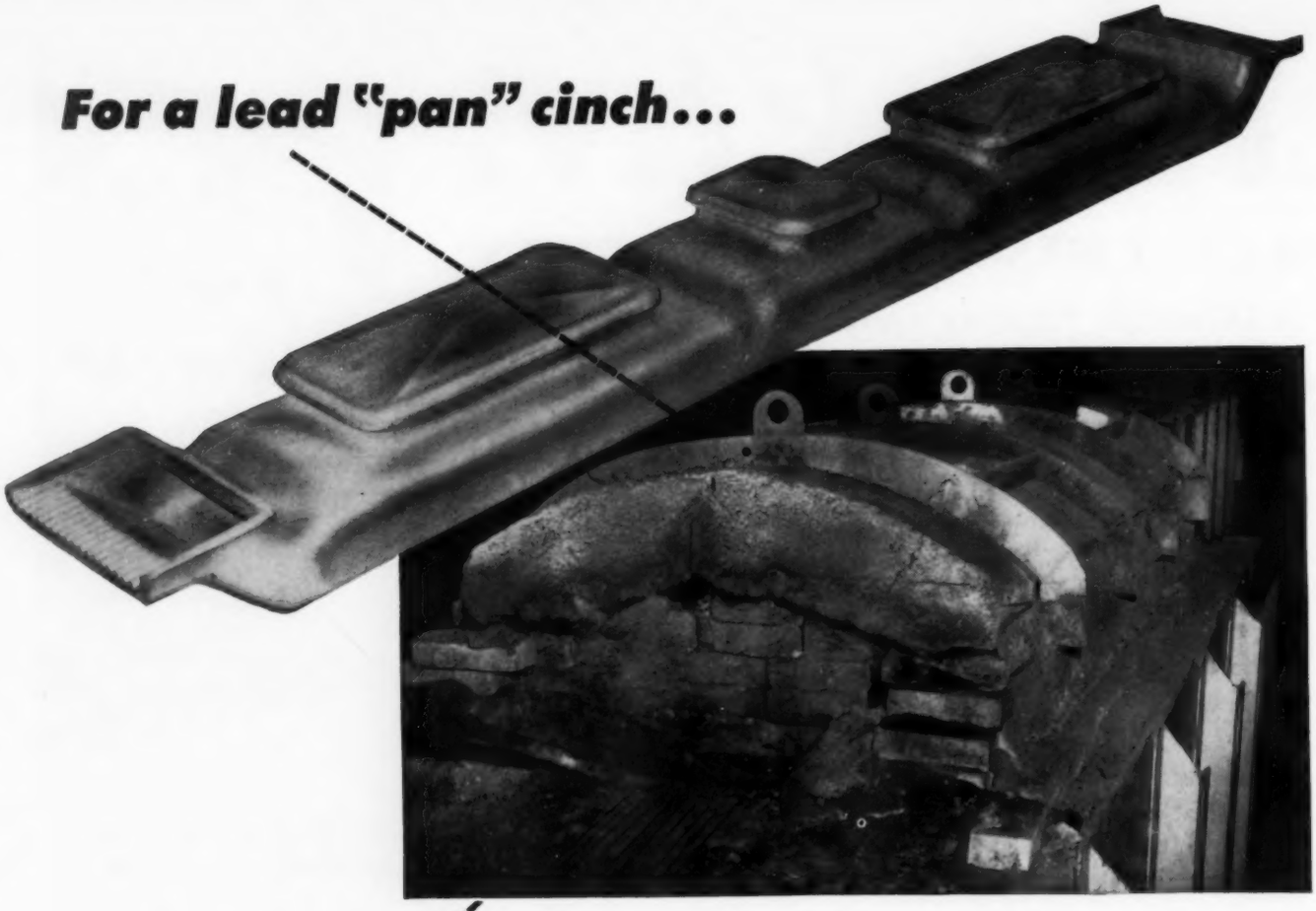
ACTION THAT SAVES YOU MONEY

By passing the word along that all purchase and stock records should call for FUSETRON fuses on loads up to 600 amps—and BUSS Hi-Cap fuses on loads above that — you get action that begets money saving.

For blowing time charts or more information on FUSETRON Fuses and BUSS Hi-Cap Fuses write for Bulletins FIS and HCS.

Bussmann Mfg. Co., University at Jefferson, St. Louis 7, Mo. Division McGraw Electric Company

For a lead "pan" cinch...



it's THERMALLOY* to outlast cast iron by 479 days!

A large steel and wire company uses a double-lead patenting furnace to give good drawing qualities to wire. In this process, wire is drawn through a "lead" pan enclosed in the furnace where temperatures range from 1600 to 1650°F.

Previously, cast iron "lead" pans were used . . . and the furnace had to shut down nearly every 21 days because the pan burned out and needed replacement. Then, a Thermalloy "lead" pan with integrally cast sinkers was installed. *To date, this pan has over 500 days of service* . . . saving this company expensive hours of repair and down time.

This is just one example of how a Thermalloy heat-resistant casting has helped a manufacturer to realize more economy in heat-treating parts. Do you have a similar need for Thermalloy in retorts, furnace parts, trays, racks, pots or muffles? Call in an Electro-Alloys engineer for full information, or write Electro-Alloys Division, 4007 Taylor Street, Elyria, Ohio.

THERMALLOY "LEAD" PAN ADVANTAGES

- Resists air-line attack, scaling and oxidation.
- Higher strength prevents sagging and distortion.
- Less weight means easier installation and less maintenance of supporting arches.
- Greater resistance to abrasion.

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

PITTSBURGH STEEL COMPLETE COLD MILL FACILITIES

▲ FORMAL opening of Pittsburgh Steel Co.'s new cold rolled sheet mill at Allenport, Pa., marked completion of the final phase of a four-year transformation under a $65,000,000 expansion program.

The new cold mill is located adjacent to the company's recently installed hot rolling mill. With both the hot and cold rolling mills in operation, the production of sheet steel at Allenport can be built up to about 750,000 net tons a year.

The new cold rolling mill is a four-stand, four-high, 66-in. tandem mill designed to operate at delivery speeds up to 3170 fpm. Extra heavy housings permit future use of the mill for rolling stainless or tinplate.

Individual motors in twin drive arrangement drive each work roll in the mill, with two 1500-hp units on No. 1 stand and two 2250-hp units on each of the other stands. A 1200-hp motor drives the reel. All stands are provided with offset gears.

All main drive motors operate under adjustable voltage and receive power from motor-generator sets of 14,200-kw total capacity. Each drive motor is supplied by its own generator. The drives are equipped with a 400-cycle magnetic amplifier control system, giving rapid response, high accuracy and low maintenance.

The mill is equipped with indicating tensiometers between stands, an X-ray thickness gauge at the delivery end of the mill and a continuously recording thickness indicator.

Coils weighing up to 60,000 lb are fed to the tandem mill down a long ramp with three hydraulically operated stops. This permits one coil at a time to be rolled into the coil positioner in the coil box. The end of the coil is then inserted between pinch rolls that feed the sheet into the first of the four tandem mill roll stands.

After cold rolling in the tandem mill, the sheet steel is annealed to restore its ductility and make it suitable for stamping and deep drawing. Coils are moved from the tandem mill by a coil buggy, then along a coil ramp with three hydraulic stops, and are then transferred to the annealing department. Here, they are upended, stacked on heavy circular load bases, and covered by cylindrical inner covers 6½ ft in diameter. Four of these bases loaded with coils and jacketed with an innercover are then housed in one of the ten portable coil annealing furnaces.

Each of the coil furnaces is slightly more than 8 ft wide by 34 ft long, and nearly 12 ft high, built of ¼-in. steel plate lined with 9-in. insulating brick.

Heat is supplied by gas-fired radiant units along the inside of the furnace walls. Fuel consumption ranges from 800,000 to 1,200,000 Btu per ton of sheet annealed. Inside the coil bases, heat is circulated by combustion air blowers, each rated at 4300 cfm. Atmosphere inside the innercovers is carefully controlled to prevent oxidation of the steel during the annealing period.

Figure 1 — Sheet steel is cold rolled on this new 66-in. four-stand four-high tandem mill. The mill housings on each stand weigh nearly 200 tons.

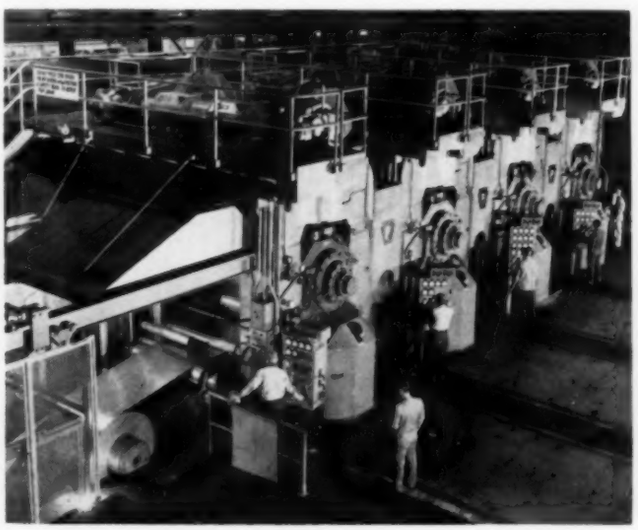


Figure 2 — To restore ductility to the cold rolled sheet, coils are annealed. Stacked on heavy circular bases, and encased in a round innercover of steel plate, they are then housed in one of the ten portable coil heating furnaces.

In addition to the ten coil heating furnaces, two furnaces are designed for annealing sheets in cut lengths for special customer requirements. These sheets are stacked on rectangular bases, and their innercovers are 7 ft wide by nearly 19 ft long, and about 8 ft high. One of these fits under one of the sheet furnaces, nearly 10 ft wide by about 21 ft long, made of ¼-in. steel plate and lined with insulating block. Sheet furnaces are heated in the same way as coil heating furnaces, except that the sheet base has no circulating fan.

Annealing time ranges from 30 to 60 hours, depending on the size of the charge and the grain structure desired in the steel.

After annealing, the steel receives a light cold rolling pass in a 21-in. and 53-in. x 66-in. four-high temper mill. This mill, powered by two 1400-hp motors in twin drive arrangement, is equipped to roll either coils or individual sheets. Coils are ramp fed to a cone payoff reel. Sheets are fed from a pack tilter, 24 ft long, and across a removable 30-ft conveyor with a belt 40 in. wide. The mill operates at speeds up to 2650 fpm.

Coils feed onto a tension reel capable of exerting an eight ton pull. Sheets are carried on a 24-ft removable conveyor, go through a roller leveler housing 17 leveling rolls, an oiling machine which lightly coats the surface to inhibit corrosion, and are stacked on a 24-ft piler conveyor, then carried off on another runout conveyor.

The temper pass makes only a slight reduction in the thickness of the sheet steel, less than 0.5 per cent, improving the finish and surface, and producing a sheet that is flat, uniform to gage, and tempered to customers' requirements for fabricating and forming operations. Near the temper mill, a metallurgical control station carefully tests the material to assure a top-quality product.

At this stage of production, most of the sheet steel processed in the cold mill is ready for shipment. Either before or after it leaves the temper mill, however, it may be sheared on a flying shear line.

The coils of sheet steel are fed to the shear line from an overhung expanding mandrel. The material entering through pinch rolls and passing over a table into a side-trimming unit that trims the edges of the sheet to exact width. Then, it passes through a 10-roll flattener, and as it emerges, is cut to lengths of from 2 ft to 16 ft by a guillotine-type reciprocating shear.

A conveyor carries the sheets to a 17-roll leveler, after which they are individually inspected. Prime sheets of top quality are then stacked on a hydraulic lift piler, weighed, and readied for shipment.

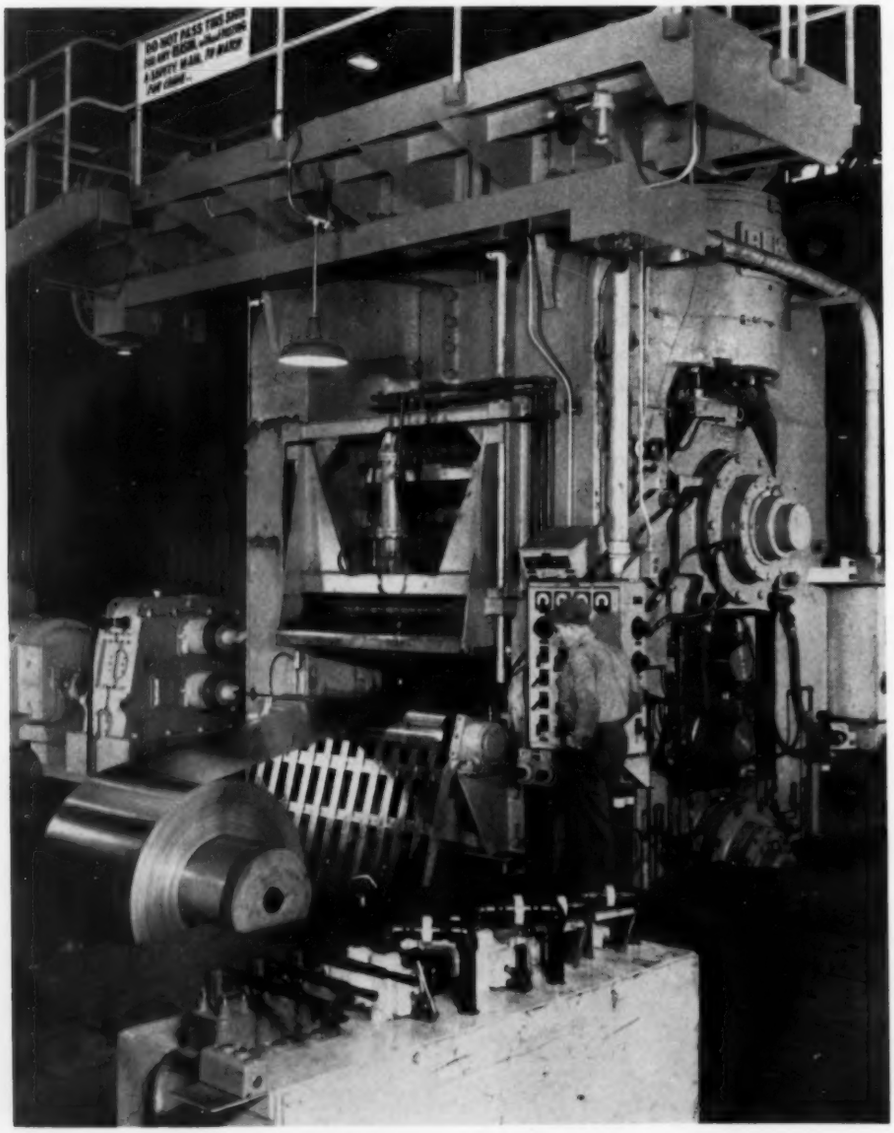
Coils of sheet steel up to 60 in. wide also may be slit to narrow width on the mill's slitting and recoil line. Here, the sheet is fed from a payoff reel through a down cut shear, which drops off the ends of the steel; then it is slit into individual strips as narrow as 6 in. wide. This line is also used to make smaller coils to meet customers' requirements.

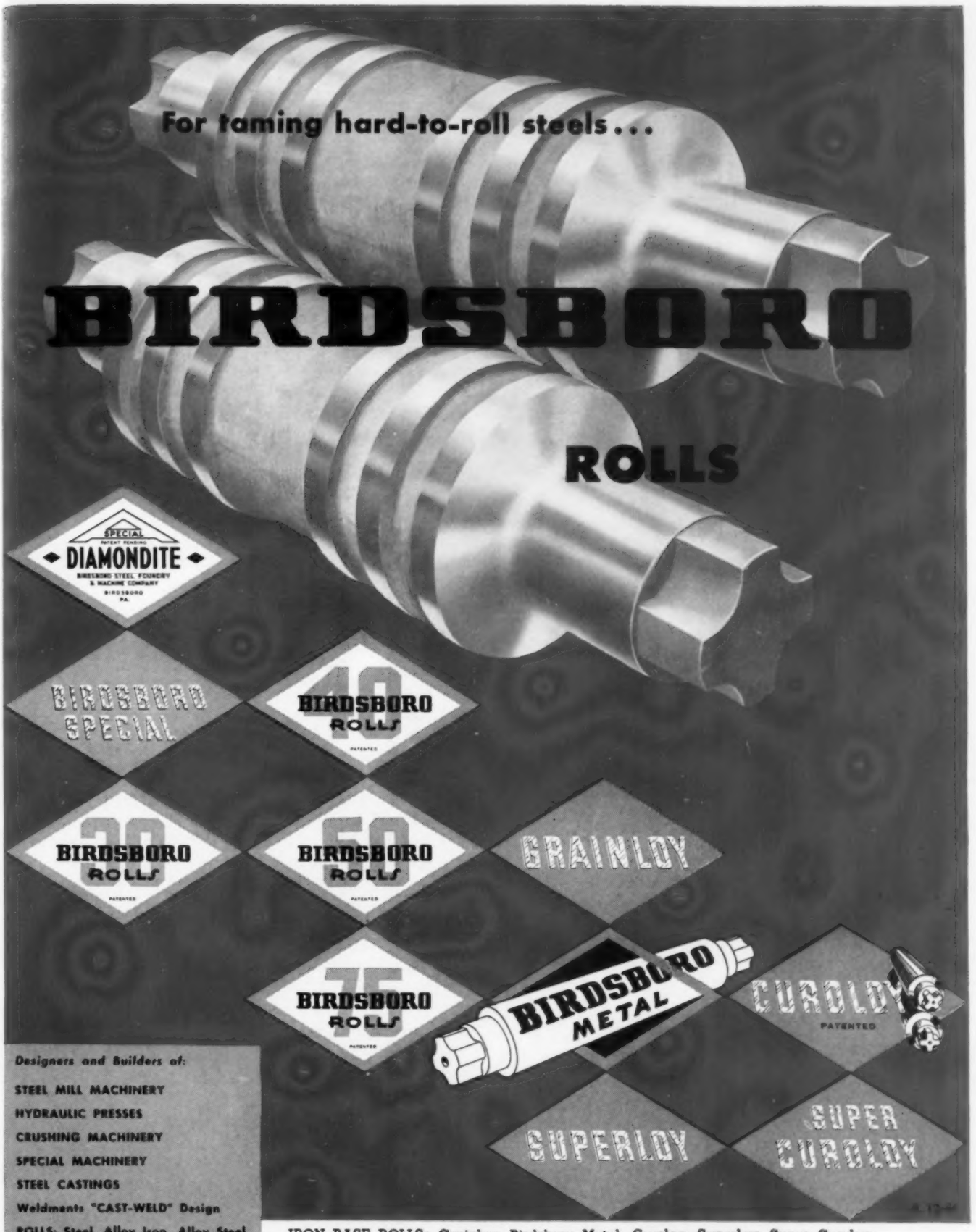
These individual strips are taken off on a tension reel of the expanding drum type, which recoils the strip into individual coils. As many as ten coils may be slit from the single 60-in. coil entering at speeds up to 450 fpm.

Sheets may also be accurately cut to widths and lengths of close tolerance on one of the two resquaring shears—both equipped to resquare steel up to ½ in. thick. The small one handles sheets up to 6 ft long. The large one will take sheets up to 15 ft long.

All sheet made in the mill follows a flow of production that carries it onto the shipping floor, either in coil form or in stacks of sheets. Handled by 15-ton tractors, or 30-ton cranes, the sheet is packaged on a central banding and packaging line, and is ready for shipment by rail, truck or barge.

Figure 3 — Temper rolling, after the steel has been annealed, reduces the thickness of the sheet less than 0.5 per cent, giving it a more dense surface and producing sheet that is absolutely flat and completely uniform.





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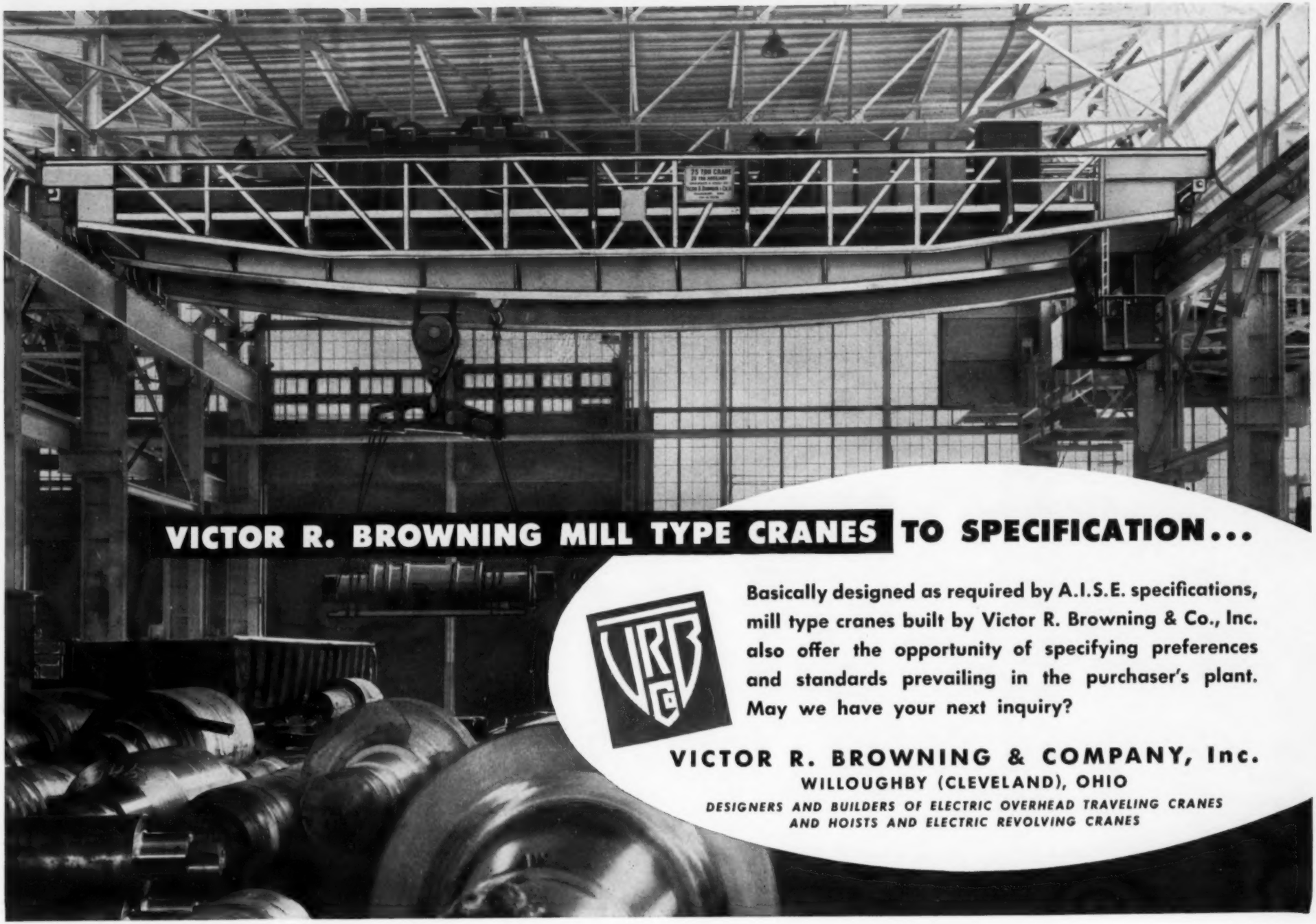

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Basically designed as required by A.I.S.E. specifications, mill type cranes built by Victor R. Browning & Co., Inc. also offer the opportunity of specifying preferences and standards prevailing in the purchaser's plant. May we have your next inquiry?

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WILLOUGHBY (CLEVELAND), OHIO

DESIGNERS AND BUILDERS OF ELECTRIC OVERHEAD TRAVELING CRANES AND HOISTS AND ELECTRIC REVOLVING CRANES

U. S. STEEL UNVEILS NEW COAL MINING MACHINE

. . . . unit described is small and provides good flexibility of operation . . . .

▲ A newly developed continuous mining machine that vibrates coal from the mining face is now in operation in several mines of the United States Steel Corp. Invented by K. L. Konnerth, vice president, U. S. Steel's coal operations, the new machine minimizes and in some cases eliminates the need for blasting.

The Konnerth machine consists basically of the main body, which includes the motor, transmission case, hydraulic tank, pumps and caterpillar drive units; the cutter bars; the conveyor and the coal-hammer carriage.

The vibratory force is applied to the coal face through two electric hammers mounted on a telescopic carriage. Hydraulically operated cylinders raise and lower the hammer carriage to a maximum of 80 in., extend and retract the hammers to a maximum of 34 in. and swing the carriage turntable to the left or right within the limits of the shear bars. Through these limits the vibrating hammers can be utilized to trim roof and break down coal at the face.

The hammer is a cylinder upon which are assembled two pulsating-current electro-magnets. The laminated iron of the magnets is solidly welded to the cylinder to form a unit assembly. The piston or core is free to slide back and forth between two bearings positioned one at each end inside the cylinder. The stroke is established by a core stop at the back end of the cylinder and a vibrating tool shank in a bushing at the other end. A pre-loaded coil spring holds the core stop in position and absorbs the piston's return-stroke energy. Another pre-loaded coil spring is set against a spring seat on the tool end and serves to limit the stroke when the vibrating tool is operating in free air and not against a coal face.

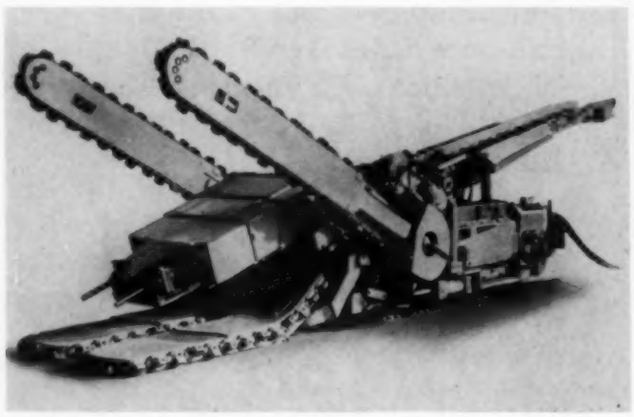
In operation, each coil is alternately excited by single-phase alternating-current through an oil-immersed selenium rectifier. This produces a pulsating direct current which is in step with the frequency of the alternating current supply. The piston is reciprocated, striking the tool at one end and the spring-loaded core stop at the other. The difference between the overall length of the piston and the distance between the two stops establishes the length of the stroke. Normal power supply to the rectifier must be 150 volts, 30 cycles and the overall alternating current input to the hammer is 80 to 90 amperes.

The number of piston strokes is established by the 30-cycle frequency when rectified, giving 30 x 2 x 60 or 3600 total reciprocations; and since only half this number strike the shank of the tool, the resultant cyclic speed is 1800 blows per minute. The force of each blow, measured by a strain gage, with the hammer mounted on a special test stand, is approximately 30,000 pounds.

Power for the electric hammers is supplied through a nine-conductor cable, from an explosion-tested mo-

Figure 1 (below) — Vibration is the principle used by the miner which mines coal from seam to shuttle car in a continuous operation. Photo highlights side shears bottom shears, caterpillar drive, conveyor and coal hammer carriage, among the principal elements of the miner.

Figure 2 (right) — Coal falls before vibratory blows delivered by Konnerth miner at the rate of 1800 per minute to the working face of U. S. Steel's Palmer Mine. Traveling less than an inch, the hammers pack 15 tons of force behind each blow, set coal loose by vibration.



tor-generator set consisting of a 15-hp, d-c motor directly coupled to a 28.8-kva, 160-volt, 30-cycle generator and a 3-kw exciter for generator excitation. The unit and the starting resistance and contractors for the d-c motor on the machine are mounted on a portable three-wheeled truck which can be parked in a breakthrough within approximately 550 ft of the machine. The limit of this distance is controlled by the length of cables that can practicably be handled between the motor-generator set and the machine.

The physical dimensions of the standard-model machine are as follows: 6 ft 6 in. wide, 22 ft 6 in. long over the main body, with an additional 8-ft overhang of the rear conveyor, making the total overall length 30 ft 6 in. The tramming height is 48 in. and the maximum mining height is 80 in. The weight of the machine is approximately 46,000 lb.

The operator's control levers are provided on both sides of the machine at a point 11 ft back from the end of the cutter bars. The starting controller and reversing cylinder are mounted on one side of the machine only, but an emergency stop switch is provided on both sides of the machine.

The machine is powered by one compound-wound d-c motor. It is totally enclosed, fan-cooled and is rated 70 hp for 3 hr or 90 hp for 1 hr. All operations such as cutting, tramming and conveying are performed mechanically and are controlled through hydraulically-operated disc clutches. All positioning operations are performed by hydraulic power which is provided by pumps through an independent hydraulic system. The caterpillar-drive units are operated at a tramming speed of 104 fpm and a sumping speed of 36 in. per min.

The bottom bars and chains serve the dual purpose of undercutting the coal and conveying it from the mine floor to the discharge conveyor. The coal is conveyed by the cutter chains and bits in the 11-in. space between the bars. The 43 blocks, making up each chain, are connected with universals so that the chain can follow the vertical angle in the bars. The speed of these chains is 315 fpm. The standard 9-ft 9-in. length shear bars are mounted on both sides of the machine and swing independently through vertical arcs from top to bottom. Standard cutting chains made up of 41 blocks each are used on the shear bars and are driven at a speed of 390 fpm.

The coal is discharged by the combination conveyor-cutter chains into a hopper located in the center of the main body of the machine. The coal is moved from the hopper to the shuttle car by a single-chain, flight-type conveyor, which travels at a speed of 290 fpm. The chain operates in a conveyor boom which extends 8 ft beyond the rear bumper of the machine and will swing 65 degrees to either side of center, and can be elevated 38 in. above the horizontal at the discharge end.

With the new machine a mine section can be operated with a three or four man crew consisting of a miner operator and two or three helpers. Specific duties are not assigned to the helpers for they function as crew members responsible for all preparation work done in the operating area. Each one is familiar with operation of the machine, the shuttle car and with the roof-bolting cycle at the coal face.

What's your cylinder problem?

Big one: Anker-Holth Rotating Hydraulic Cylinder with 21" bore and 20" stroke, for 3000 psi. Little one: Anker-Holth Air Cylinder with 3" bore, 3" stroke.

Anker-Holth has the answer!

• Your problem in power motion may be far removed from the Anker-Holth Cylinders shown above. Whatever your need for air or hydraulic cylinder power, Anker-Holth has the engineering know-how and manufacturing facilities to match your specific requirement. Anker-Holth engineers will gladly assist you. Call or write Anker-Holth Division of The Wellman Engineering Company, Dept. E-9, 2723 Conner Street. Port Huron, Michigan.

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THE WELLMAN ENGINEERING COMPANY

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Tips On Battery Room Layout

By K. A. VAUGHAN
Manager, Field Engineering
Gould-National Batteries, Inc.
Trenton, N. J.

▲USERS of battery-powered industrial trucks will save time and money by giving careful consideration to battery-room layout, location, and services to be offered when designing a new shop or remodeling an old one. The efficiency of the battery maintenance and charging room will affect overall material handling in the entire plant for years and its functioning should be considered in relation to the overall handling system as it exists now and how it may change in the future.

What do you wish to accomplish in the battery room? Some small shops perform only battery charging and the simplest maintenance required for good operation. Because the distances are not great in a small plant, the charging room location is not of critical importance. In a very large plant, however, using hundreds of trucks scattered over many acres, the problem becomes more complex. Large battery users may find it economical to repair damaged batteries themselves rather than send them to the manufacturer's factory or local service station. The most elaborate set-up may even include complete rebuilding and assembling facilities. In many large plants the trucks themselves are often maintained and repaired close to the battery-room under the same foreman by the same personnel (Figure 1). It has become common practice in recent years in large plants to place charging stations throughout the plant so that trucks do not travel long distances for a recharged battery and can get booster charges during the lunch period.

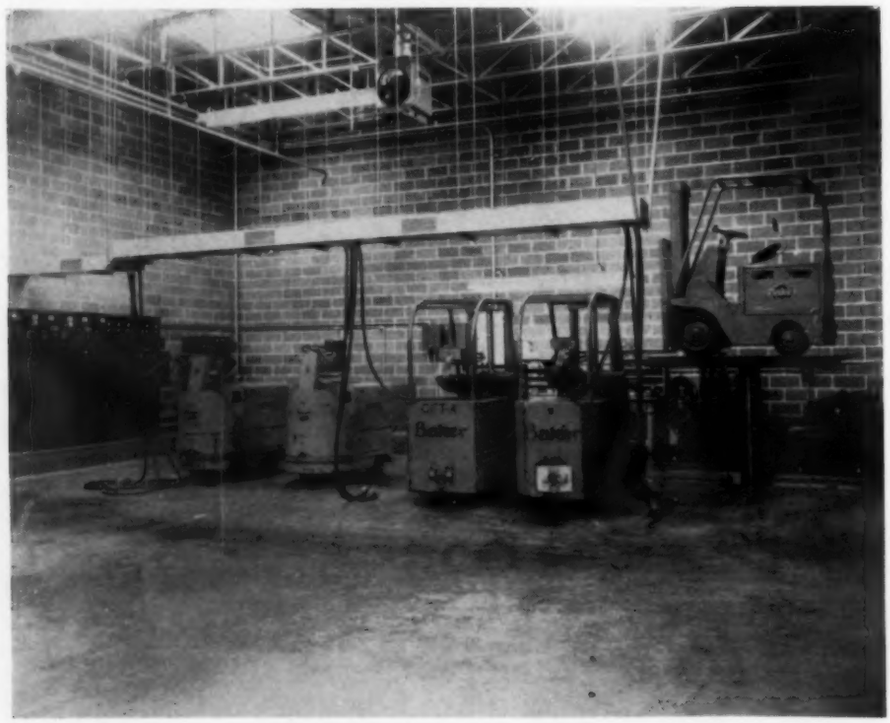
Another fast-growing practice in large plants involves changing batteries on the job. The recharged battery is brought to the truck in its working area rather than have the truck travel to the battery-room. Some continuous production processes are so critically balanced that industrial trucks cannot leave the job long enough to travel to the battery room. Truck maintenance such as greasing is also commonly done on the job.

With all these variables, a few general principles will serve as a guide in battery-room layout. Specific details will depend on the number, size and type of batteries, and duty cycles.

Important considerations in selecting the location for the shop are the availability of power, the ease of ventilating the shop, and the distance trucks must travel to charge batteries. Time required for trucks to return to the battery shop can be decreased by placing the shop at the center of the trucking operations. If the shop is very remote from truck-working areas in a large plant, it may become advisable to spot charging stations throughout the plant.

Provide for expansion of the battery shop as the plant grows and more battery-powered equipment is used. In addition, it has been found that once industrial trucks are introduced into a plant for one purpose, so many additional uses are found for them that the number of trucks bought increases even though the size of the plant remains constant.

Figure 1 — Battery charging is often combined with truck maintenance. Batteries are charged in trucks. Truck in background is on grease rack for maintenance and repairs.



Cross-section shows water-tight terminal box and protected leads.

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Ribbed manganese bottom plate and solid pole shoes on under side of Type SW magnets.

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1703

The possible expanded use of industrial trucks in a plant must be considered when selecting the charging equipment. Generally, multiple units of equal capacity motor-generator sets are chosen rather than one large charging unit because of greater flexibility. When more charging units are bought as truck fleet grows, capital investment is distributed over several years. In addition, consider the possibility of using handling equipment that will require larger capacity batteries in the future and, therefore, larger capacity charging equipment. If all charging is based on using 15-cell batteries and then later on 18-cell batteries are needed, charging equipment will not be fully adequate to charge the larger batteries in the time allowed.

Give thought to selecting the best charging method for your purposes. Possibly sequence charging will offer advantages in a particular plant.

Equipment arrangement in the shop depends, of course, on the type and amount of equipment to be included. A completely equipped battery shop contains the following items:

1. Hoist with spreader bar or truck for handling batteries.
2. Racks to hold batteries during charging and storage.
3. Charging equipment (motor-generator sets or circuit chargers).
4. Maintenance instruments and tools (hydrometers, voltmeters and thermometers, etc.).
5. Battery washing facilities (wire brush, grease, neutralizing solution, rags).
6. Distilled water source.
7. Cleaning hose (water, air or both).
8. Small office.
9. Work bench.
10. Spare parts.
11. Repair equipment (cell pullers, arc welder, drills, etc.).
12. Safety equipment (rubber gloves, aprons, goggles).

In laying out this equipment, the main considerations are safety, reduced handling and working convenience.

The first operation for most shops is to remove the battery from the truck. A two-ton hoist with a spreader bar mounted on a monorail is the best equipment for this job. The monorail should cover the racks and run the length of the shop so that batteries can be moved easily anywhere in the shop. If a fork-truck or walkie is used, more space must be allowed for the trucks to operate.

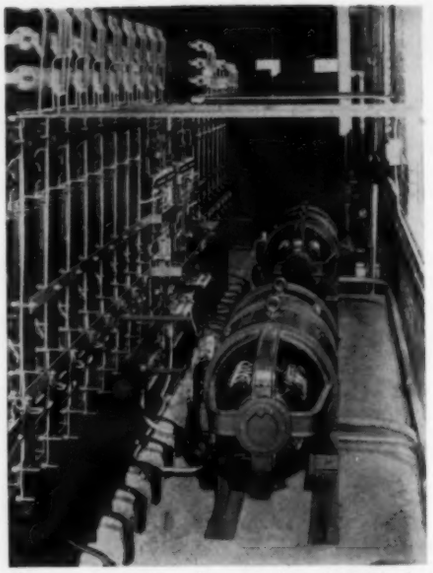


Figure 2 — Charging unit should be close to control panel.

Just as the battery shop is the core of the materials handling operation, the charging racks are the core of the shop. When locating the racks, make sure that attendants will be able to move around them and reach all batteries easily. In some plants the best position for the racks is in the center of the room. In others they may be placed along the wall to advantage. They should be long enough to provide space for the maximum number of batteries to be charged at one time, allowing for handling space between batteries. The racks should be about the width of the battery and of a height that will bring the tops to a comfortable working level. Mount separate charging leads for each battery-space on the rack. Avoid long leads because they cause power loss.

Because charging and simple check-ups are the most frequent maintenance operations, reduce battery handling by doing these jobs in the area nearest the battery changing point. Install the charger control panel close to the charging equipment without making it difficult to move around them. The charging rectifier or motor-generator set usually does not require attention during battery maintenance; but, for its own maintenance, it should be accessible to electricians and should be close enough to the control panel to allow reasonably short wiring connections (Figure 2).

Provide a cabinet to hold maintenance tools and instruments such as hydrometers, voltmeters, thermometers, etc. Convenient location of tool cabinet and charger control panel reduces maintenance time and motion.

Mount the distilled water container on a wheeled cart or on the overhead monorail to eliminate lifting. Keeping distilled water above the cell makes it possible to water batteries by merely opening a valve on a rubber hose instead of by pouring.

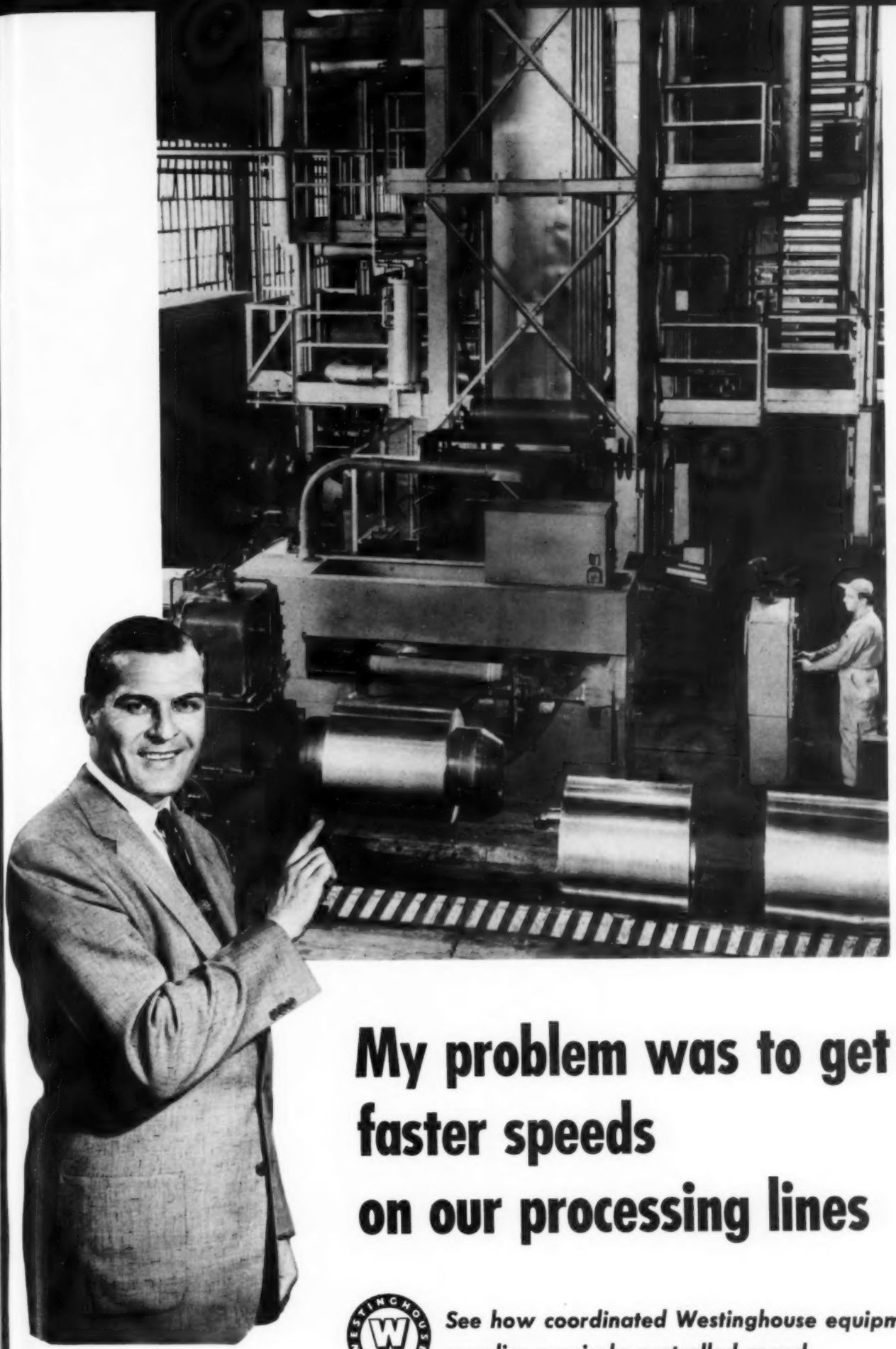
Batteries are ordinarily cleaned only once a week, so the cleaning hose need not be next to the battery changing area. If water cleaning is employed, make sure to locate hose and sink so that there is little danger of splashing water onto parts which may corrode, or on sensitive equipment. Air-hose is effective for drying.

A small office should be set up to keep complete battery records and schedule maintenance.

Smaller shops often take care of major battery repairs by returning the batteries to the manufacturer or to his local service station. If the plant shop does its own battery repairing, allocate space for spare parts, work bench, and repair equipment. The repair area need not adjoin the area where the batteries are removed from trucks, but should be covered by the hoist.

The work bench should be 2½ ft wide, 10 ft long, and have a heavy-duty vise mounted securely on one end. A part of the bench should be covered with a clean rubber mat, rather than wood, on which acid-soaked parts can be placed for examination without damaging the bench. Store spare parts such as cell and tray containers, connectors, covers, etc., in shelves about three ft wide. If the shelves are mounted six to eight feet above the floor, this storage space will not become cluttered with miscellaneous material.

In large battery shops the list of repair equipment includes lead burning equipment, putty knife, cell puller, moulds, drills, compound knives, thermometers, hydrometers, voltmeters, etc. Most battery shops do not have such extensive equipment; but, in any case, all repair equipment should be kept in one wall-mounted cabinet near the work bench.



My problem was to get faster speeds on our processing lines

See how coordinated Westinghouse equipment supplies precisely controlled speed

Constant speed and no stops... couldn't do it without automatic control

Take your annealing line, for instance. You need constant speed through the furnace in order to produce uniform quality steel. You must maintain nonstop operation for long periods.

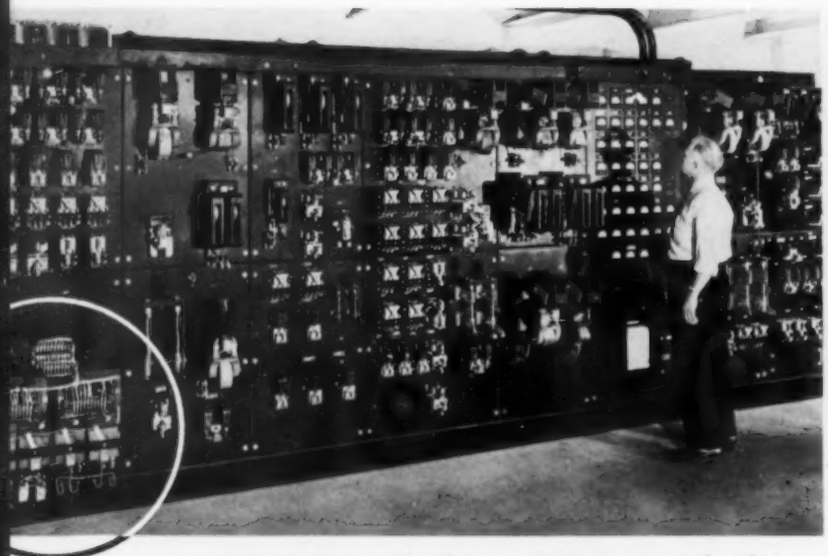
Westinghouse regulating systems, with their coordinated basic control, give your crews full automatic control of temperature, edge position, strip tension, loop position, overspeeding and resynchronization, and master-line speed. Rototrol® or Magamp® current regulators accurately control strip tension along the line, and keep speed constant through the furnace. On electrolytic cleaning lines, higher line speeds and larger coils require more accurate tension control. Proper regulator design and characteristics are the answer to the problem. Equipped with inertia compensating circuits, the regulator keeps strip tension constant at uncoiler and reel during accelerations and decelerations.

Every second counts if you're shooting for high-production pickling lines. Entry section must keep pace with the continuous process through the acid tanks. Fast acceleration and deceleration must overcome the stops that come every few minutes for welding on new coils. Westinghouse regulators speed up this start-stop process by forcing the section generator voltage to build up rapidly.

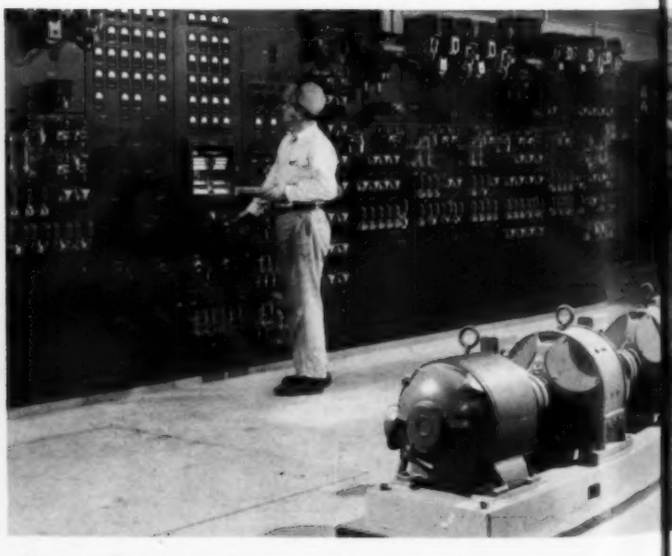
Rototrol holds constant the generator voltage when you reach production speed. A magnetic regulator at the acid tanks and a Westinghouse Photothyraton regulator at the delivery pit accurately control the depths of loops. Another timesaver: automatic speed-up of the upcoiler and the side trimmer, after the delivery end cuts out the weld, gains time in ejecting the full coil and in entering the oncoming strip in the upcoiler bending rolls.

YOU CAN BE SURE... IF IT'S

Westinghouse



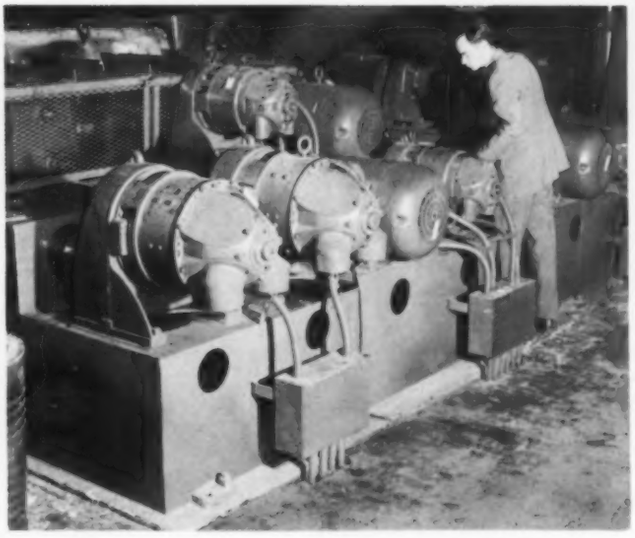
No moving parts, no brushes, no commutators, no bearings, no tubes to burn out—that's Magamp. Here (lower left) it regulates winding reel speed on 3000-fpm preparation line.



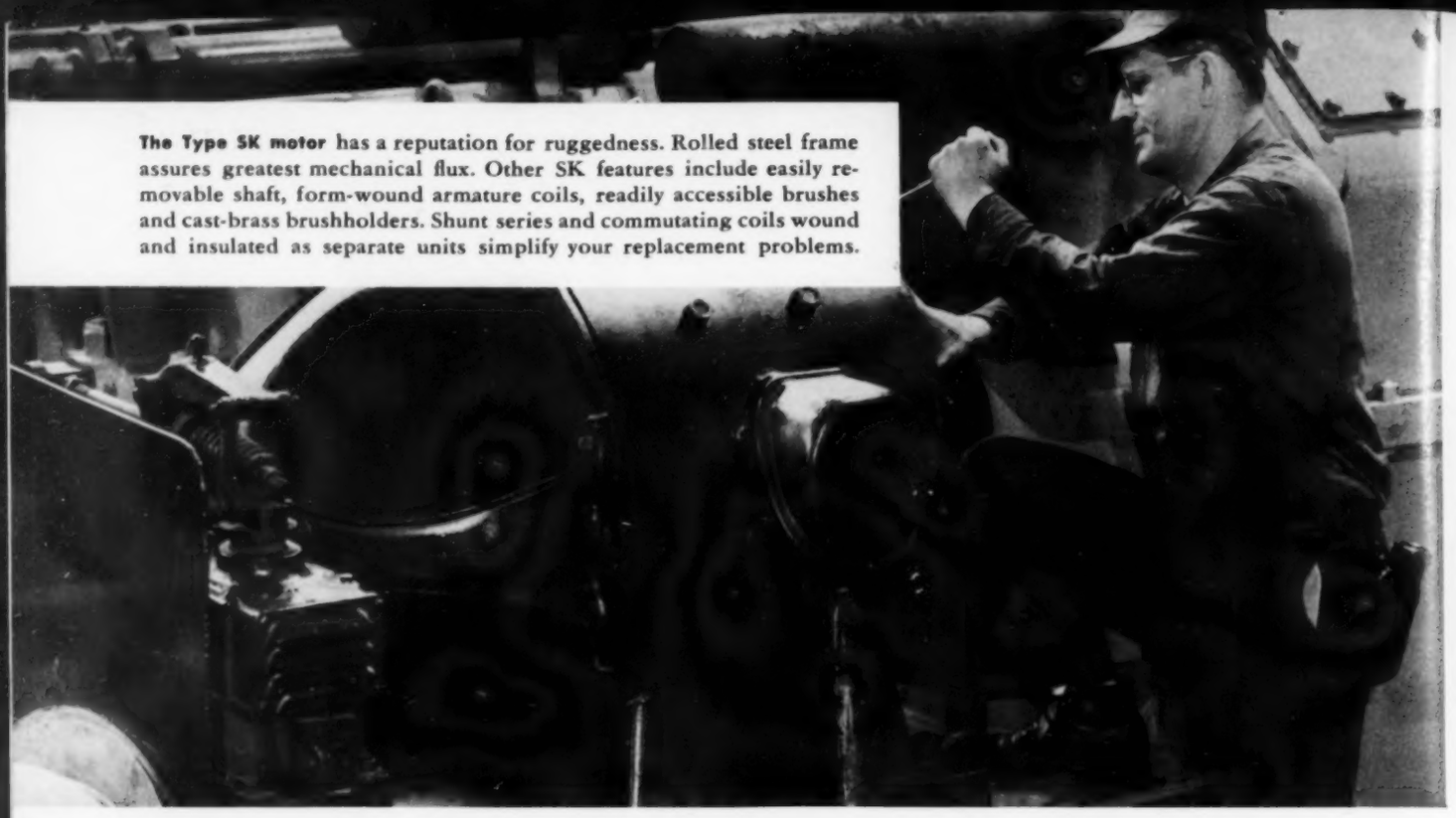
Fast acceleration and current-limit protection come from Rototrols (foreground) in this 72" pickling line control room. Westinghouse engineers plan installations like this.

Many customers like this Westinghouse type of operator's station—floor mounted and cabinet construction. Time for each phase of operation is checked by cycle counter. Switches permit selection of normal or stand-by controls.

Edge regulator consolidates all of its control and rotating equipment in a single, floor-mounted enclosure. Blower and filter, on top, pressurize cabinet to exclude dust and dirt.



Quiet but tough, these 3-hp and 5-hp Westinghouse gear-motors drive submerging rolls and scrubber back-up rolls. Simple splash system lubricates the gears and bearings.



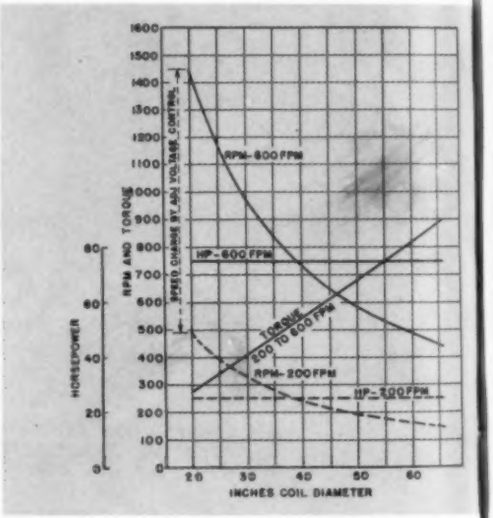
The Type SK motor has a reputation for ruggedness. Rolled steel frame assures greatest mechanical flux. Other SK features include easily removable shaft, form-wound armature coils, readily accessible brushes and cast-brass brushholders. Shunt series and commutating coils wound and insulated as separate units simplify your replacement problems.

Westinghouse motors helped us kick up our speed, widen our range

D-c motor characteristics are especially critical when your operating ranges are widened and maximum speeds climb. That's true on coil preparation lines where threading speeds are fixed by the operator's ability to handle the strip and thread the line. With rapid acceleration and deceleration needed, short-time torque build-up ratings on main generator and drive motors may be the deciding factor in machine-size selection.

Westinghouse Type MC mill motors with cast steel frames have been especially designed for heavy-duty applications. The low inertia armature allows motor to start, stop and reverse with a minimum of power. Wedges made of Class B material replace bands for holding coils in slots. This permits easier winding and less abuse of coils during winding. Completely insulated field coil assembled on a steel shell provides exceptional durability. Commutator is of bolted construction, assembled on a steel bushing and insulated with mica V rings.

Westinghouse maintenance facilities include 38 Apparatus Repair Shops, 31 Renewal Parts Warehouses, and 46 Field Service Offices. Telephone your Westinghouse representative for any of these services. Westinghouse Electric Corporation, Pittsburgh 30, Pennsylvania.



Operating requirements of 75-hp, 400/1600-rpm reel drive at full tension. Line speed—200 to 600 rpm. Coil diameter—20" to 66".

MP-3010

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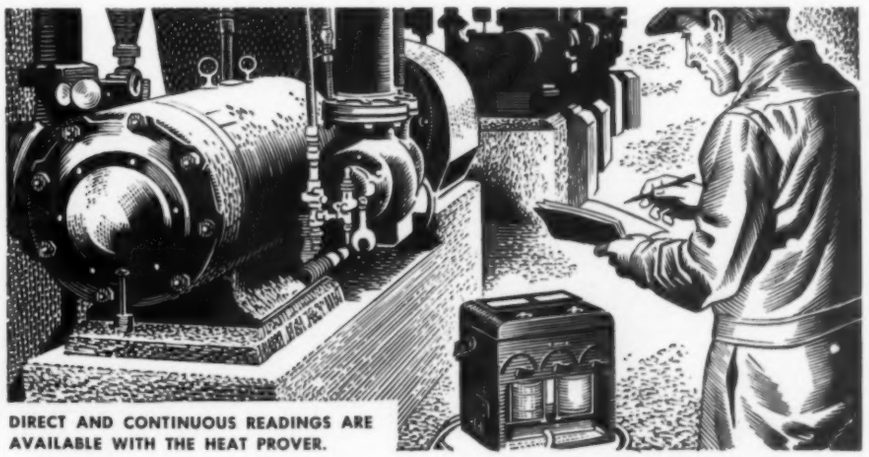

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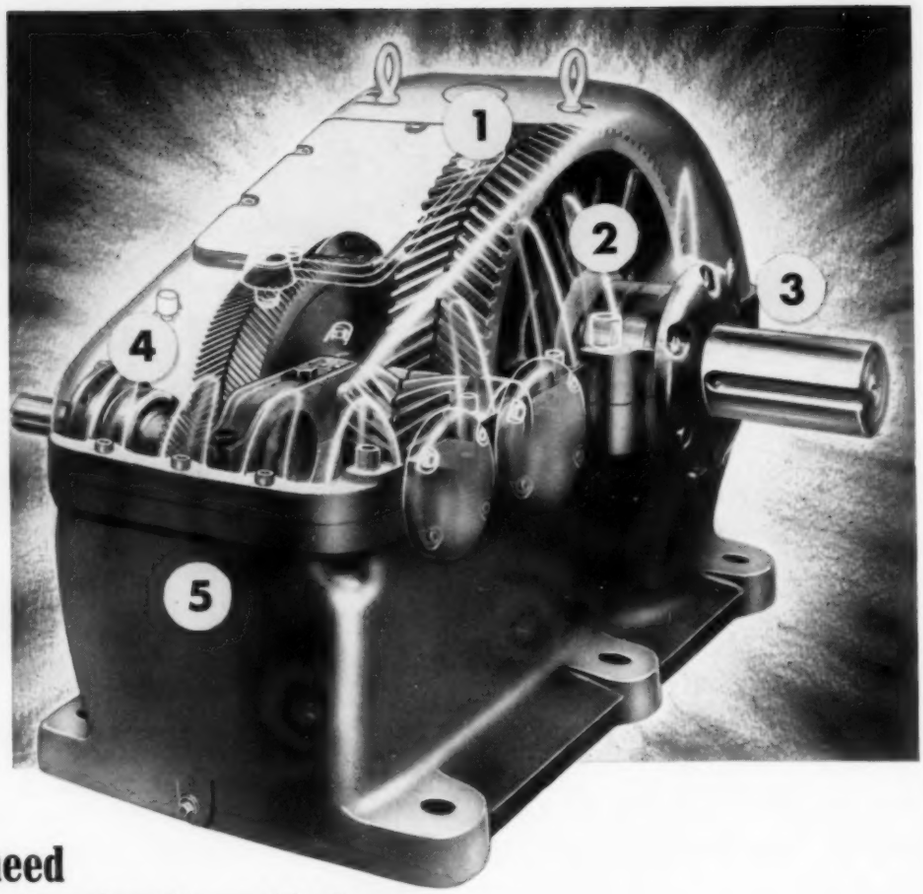

When you need high-hp speed reduction with heavy shock loads, Link-Belt gives you

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BECAUSE they withstand heavy shock loads, Link-Belt parallel shaft drives are the low-cost answer for many high-hp speed reduction problems. Simultaneous engagement of several teeth assures smooth operation and great load carrying capacity.

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Link-Belt parallel shaft drives are available in 2.84:1 to 318:1 reduction ratios, ½ to 1000 hp, 2 to 600 output shaft rpm. Ask for Book 2519.

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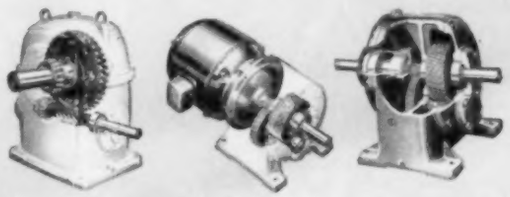
In addition to all three types of speed reducers, Link-Belt builds variable speed drives, fluid drives, chains, sprockets, couplings, bearings, shafting. All are pre-engineered for easy installation and maximum efficiency.



Worm Gear Drives — ask for Book 2324-A

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Down through history Swedish iron masters have been known for their skill in steelmaking.

To allow them to apply present-day production methods to their art Domnarfvets Jernverk has turned to Morgan Construction Company for a modern, flexible, Merchant, Rod and Strip Mill.

Morgan's experienced engineering staff designed this mill, it was built in Worcester and erected in Domnarvet, Sweden under the direction of Morgan engineers. Its production record has been consistent with the best Swedish tradition.

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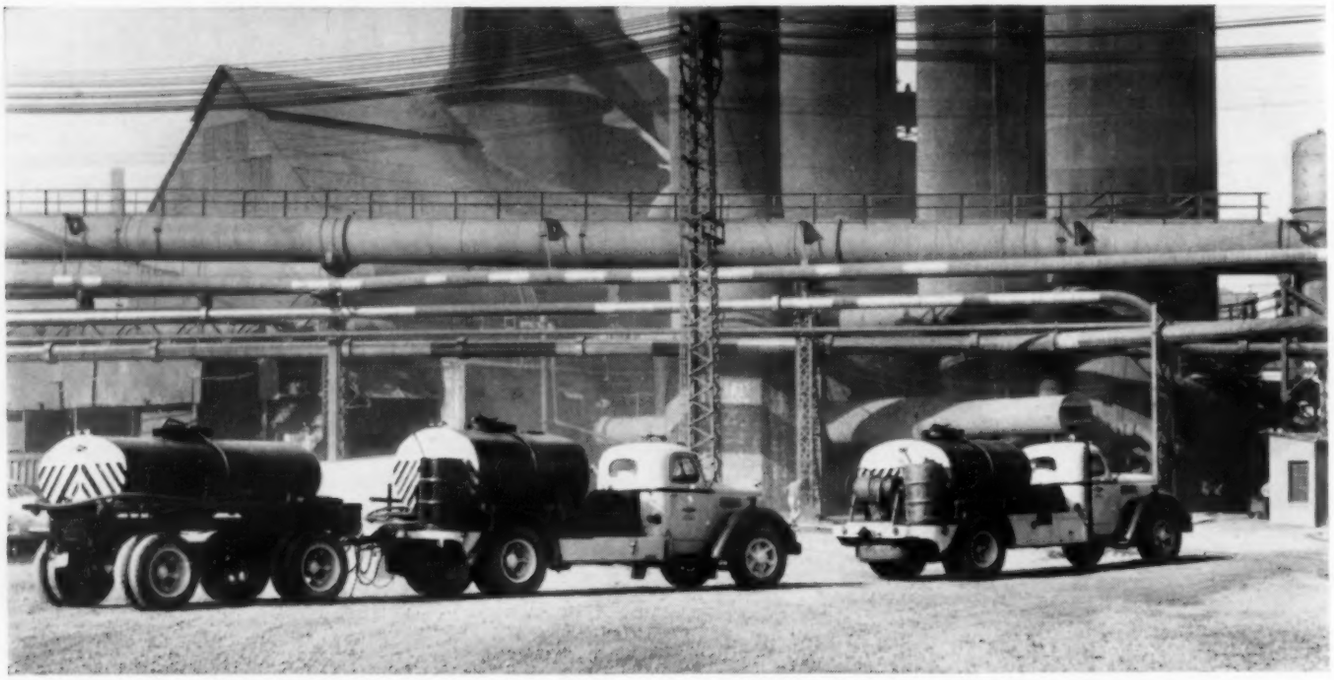
600 FEET OF COKE OVEN GAS MAIN CLEANED CHEMICALLY WHILE IN USE

DOWELL-designed jet nozzle removed brittle deposits from 30-inch gas line under pressure



Tar and naphthalene deposits had accumulated in a 600-foot section of a steel company's 30-inch gas main. The line supplied coke oven gas to a strip mill two miles away. Pressure drop through this line had doubled, forcing the company to buy large quantities of natural gas to supply the strip mill. The company's attempts to clean the line with steam and hot water failed . . . then Dowell was called.

Dowell Service cleaned the line in only three working days, using chemical solvents, specially-designed high-pressure jets and mobile high-pressure pumps. The steel company was especially pleased because Dowell Service did not interfere with the regular function of the line.

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A Service Subsidiary of
THE DOW CHEMICAL COMPANY

Date-line Diary...

April 2

▲ Lead continued its upward trend with an advance of ¼¢, selling at 13¾¢ a lb in New York and 13.55¢ in St. Louis.

▲ CIO electrical workers of Westinghouse asked for an annual wage guarantee equivalent to 40 hrs pay 52 weeks of the year.

▲ Cambria Fuel Co. of Johnstown, Pa. has notified the United Mine Workers of its intention to become non-union as of May 1.

April 5

▲ The AISI reports that operating rate of the steel industry for the week starting April 5 is scheduled at 68.2 per cent of capacity. This is equivalent to 1,626,000 tons compared with 1,648,000 tons one week ago and 2,230,000 tons one year ago. Index of production for the week is 101.2.

▲ Allegheny Ludlum Steel Corp. plans to spend $13,000,000 for capital improvements in 1954 compared with $10,500,000 in 1953 and $18,100,000 in 1952.

▲ Bethlehem Steel Co. will suspend steel and pig iron production at its Steelton, Pa. works for several weeks to reconstruct its 44-in. blooming mill.

▲ Anaconda and Kennecott have cut copper production in Chile by 8800 tons or 30 per cent monthly.

▲ The unemployment figure moved up by 54,000 for the month ending March 15, the smallest move in six months, according to the Census Bureau. This was a sharp contrast with the decline of 114,000 in unemployment ranks for the same period in 1953.

▲ Armco Steel Corp. of Middletown, Ohio has acquired all the common stock of Southwest Steel Products Co., Houston, Texas, in order to expand bar joist business in the South and Southwest.

April 6

▲ Business inventories in February rose while sales declined. Stocks held by manufacturers, wholesalers and retailers were valued at $80,300,000,000 on February 28, $2,800,000,000 higher than the 1953 level.

▲ The International Tin Study group reported that world tin plate production in 1953 reached a new high of 5,790,000 tons compared to 5,427,000 tons in 1952. Output in the United States reached a new record at 4,162,087 tons.

▲ The CIO United Steelworkers formally authorized the opening of labor contract negotiations.

April 7

▲ According to The Aluminum Association, total production of primary aluminum in February was 220,965,786 as compared with 232,493,207 lb in January and 185,297,920 in February one year ago.

▲ According to CIO Steelworkers, nearly 200,000 men or 16 per cent of their members are now idle.

▲ Follansbee Steel Corp. reported a loss of about 40¢ to 50¢ a common share for the first quarter in 1953.

April 8

▲ Sales of the entire steel industry for 1953 are estimated at above $13,200,000,000. Net income in 1953 was more than 4 per cent below 1950 although sales were about ⅓ greater. Profit was cut since steel companies were forced to absorb freight, trim extra charges, and eliminate premium prices where they existed.

▲ Scrap price moved upward to $24.50 per gross ton.

▲ A report of the ARCI stated deliveries of new domestic freight cars in March 1954 totaled 4823 compared with 3974 in February, and 6679 in March 1953. Backlog of cars on order as of April 1 was 20,966 compared with 25,441 on March 1.

▲ National production of goods and services continued to decline in the first quarter. Output ran at an annual rate of around $358,500,000,000 compared with a yearly peak of $371,000,000,000 in the second quarter of 1953.

April 9

▲ Refined copper advanced ¼¢ by custom smelters bringing it to 30¢ a lb.

▲ A United States Government loan of around $100,000,000 is probable for the coal and steel community in the European countries of France, Italy, West Germany, Belgium, the Netherlands and Luxemburg.

▲ The F. W. Dodge Corp. reports contract awards in March for the 37 states east of the Rockies smashed all March records with a total of $1,527,517,000, 25 per cent above February and 13 per cent above March 1953.

April 12

▲ The AISI reports that operating rate of the steel industry for the week starting April 12 is scheduled at 67.3 per cent of capacity. This is equivalent to 1,604,000 tons as compared with 1,622,000 tons one week ago and 2,228,000 tons one year ago. Index of production for the week is 99.9.

▲ Detroit Steel Corp.'s figures show a loss for the first quarter in 1954 of about 2¢ a share. The period one year ago earned 70¢ a share. Sales for the quarter were off from last year's $28,803,000 to $12,330,000.

▲ Barium Steel Corp. announced in its annual report net sales for 1953 amounting to $89,719,175 as compared with $99,052,029 in 1952, a drop of 9.4 per cent. Net earnings in 1953 were $2,321,140 or $1.01 per share of outstanding stock and in 1952 were $2,746,051 or $1.22 per share of outstanding stock.

April 13

▲ In London, spot tin rose 5¢ to $1.02½ a lb, which affected dealings in New York and resulted in an increase of 4¾¢ in Straits tin to $1.02 per lb.

▲ Lead advanced ¼¢ a lb to 14¢ in New York and to 13.80¢ in St. Louis.

▲ According to a report of the AISI, production of steel in March was 7,290,000 net tons of ingots and steel for castings, an increase of over 206,000 tons from the February total.

April 14

▲ Rotary Electric Steel Co. earned $1.48 a share for its March quarter on an operation schedule of 50 per cent of its capacity. The 1953 earnings were $2.09 a share on an operation schedule of 107 per cent of its capacity.

▲ Duquesne Light Co. announced the site for the nation's first full-scale atomic power plant will be on the south bank of the Ohio River near Shippingport, Pa.

April 15

▲ Republic Steel Corp., operating at 69.4 per cent of capacity, reported the March quarter operations at

33.6 per cent below one year ago with earnings declining only 19.6 per cent to $1.79 a share compared with $2.24 a share in the first quarter of 1953.

▲ The Ford Motor Co. has closed operations of its William Clay blast furnace at the Rouge plant for relining and general repairs. It has been in continuous operation since 1948.

April 16

▲ Alcoa had record sales of $707,500,000 in 1953.

April 17

▲ A report of the Bureau of Mines giving figures for consumption of ferrous materials, scrap and pig iron, during February indicated that the use of these materials was the lowest since 1950. Scrap for consumption in February was 4,477,000 gross tons, 3 per cent below January. Home scrap accounted for 2,714,000 tons and purchases 1,763,000 tons.

▲ In January and February, the total of shipments of finished steel was 11,092,411 net tons, or 2,500,000 tons below the same two months in 1953 according to the AISI.

April 19

▲ The AISI reports that operating rate of the steel industry for the week starting April 19 is scheduled at 68.5 per cent of capacity. This is equivalent to 1,634,000 tons compared with 1,622,000 tons one week ago and 2,276,000 tons one year ago. Index of production for the week is 101.7.

April 20

▲ Auto dealers' new car inventories have reached its highest level since World War II. Holdings averaged 14.3 units as of April 1.

April 21

▲ General Electric Co. reported earnings for the first quarter of 1954 at $48,029,000 or $1.67 a share, an increase of 42 per cent over the same period in 1953. Sales for this period in 1954 were $715,596,000, a decline of 8 per cent from 1953's $777,819,000.

April 22

▲ Electricity output showed a 2.9 per cent increase for the last week over the week one year ago, the smallest gain so far in 1954, according to the Edison Electric Institute.

▲ Stockholders of Lone Star Steel Co. have approved the plan to revamp its RFC debt.

April 23

▲ Kaiser Steel Corp.'s net earnings for the nine month period ending March 31, 1954 amounted to $3,828,804 or $0.65 a share compared with $5,592,091 or $1.20 a share for the same period one year earlier. Total sales for this period in 1953 were $99,513,524 as compared with $97,581,901 one year ago.

▲ According to the AISC, March shipments of fabricated structural steel amounted to 285,365 tons. Bookings in March totaled 193,509 tons. Backlog of work ahead as of March 31 stands at 1,645,452 tons.

▲ Sales and revenues for Allegheny Ludlum Steel Corp. totaled $45,614,000 during the first quarter of 1954 compared with $68,686,000 in 1953. Net earnings for the first quarter in 1954 amounted to $1,063,000 or $0.58 a share compared with $2,098,000 one year ago.

April 26

▲ Net earnings in the first quarter of 1954 for Colorado Fuel and Iron Corp. were $771,456 or $0.20 a share compared with $2,177,372 for the corresponding quarter in 1953.

▲ Armco Steel Corp. reported earnings for the first quarter in 1953 at $9,137,226 or $1.75 per share in comparison with $7,767,045 or $1.49 per share in 1953. Sales for the first quarter of 1953 were $131,346,000 compared with $143,397,000 the year before.

▲ The AISI reports that operating rate of the steel industry for the week starting April 26 is scheduled at 68.4 per cent of capacity. This is equivalent to 1,632,000 tons compared with 1,636,000 tons one week ago and 2,262,000 tons one year ago. Index of production for the week is 101.6.

April 27

▲ A net income of $529,926 (after taxes) or $0.23 a share was reported by the Crucible Steel Co. of America for the first quarter in 1954 as compared with $1,756,829 for the same period one year earlier.

▲ Inland Steel Co. announced net income for the first 1954 quarter of $9,463,250 or $1.92 a share in comparison with $6,805,150 or $1.39 a share for the same quarter in 1953. Sales were $137,590,737, up 1.5 per cent from the same quarter in 1953.

▲ A net income of $2,989,478 or 89¢ a share for the first quarter in 1954 was reported by The Youngstown Sheet and Tube Co. as compared with $6,958,975 or $2.08 a share for the same period one year earlier. Total income dropped to $105,863,413 from $140,564,614 the previous year.

▲ United States Steel Corp. reported income for the first quarter of 1954 of $44,830,376 or $1.48 a share. In 1953 net income was $49,375,958. Sales in 1954 were down 10.5 per cent to $830,000,000.

April 29

▲ Westinghouse Electric Corp. reported sales for the March 1954 quarter of $406,000,000 up 6.4 per cent from one year ago. Net profits rose 55.9 per cent above the first quarter in 1953 and averaged $1.61 a share.

April 30

▲ Bethlehem Steel Corp. made known billings for the March 1954 quarter which amounted to $445,000,000, off $55,000,000 from the year earlier level. Net income was $27,802,938 or $2.73 a share in comparison with $3.06 a year ago.

▲ CIO United Steelworkers formally requested steel companies to set an early time for contract talks before present agreements expire on June 30.

▲ Wheeling Steel Corp. reported for the first quarter of 1953 net sales of $42,018,378 and a net profit of $1,135,386 or $0.48 a share compared with net sales of $53,002,824 and a net profit of $2,962,388 in 1953.

▲ Sociedad Mixta Siderurgia Argentina, Buenos Aires, bid the high bid of $9,000,000 for the United States held steel mill owned by Czechoslovakia.

▲ National Steel Corp. reports net earnings for the first quarter in 1954 of $6,420,225 or 87¢ per share compared to $11,087,933 or $1.50 per share in 1953.

▲ Jones and Laughlin Steel Corp. reports for the first quarter in 1954 total sales and operating revenues of $127,880,000 with a net income of $5,821,000 or $0.88 a share compared with sales of $158,914,000 and net income of $5,642,000, or $0.85 a share in 1953.

▲ Lukens Steel Co. declared a net income of $1,317,972 for the first two quarters of its 1954 fiscal year ending April 10, compared with a net income of $1,933,342 for the corresponding period in 1953. Net sales were $37,913,736 in 1954 compared with $45,303,938 in 1953.

▲ Barium Steel Corp. announced a net loss for the March 1954 quarter amounting to $28,755 or about 1¢ a share. Sales amounted to $12,385,293 as against $26,219,665 for the same period one year ago.

Sixty-ton Bedford Crane with air-conditioned cab in the new melt shop of The Timken Roller Bearing Co., Canton, Ohio. Working directly over the severe flash heat of top charging electric furnaces, it positions and dumps approximately 40 tons of scrap per swing.

Bedford Cranes are backed by 52 years of specialized experience

Proof of the superiority of Bedford Cranes is found in the high percentage of *repeat orders* from important owners through the years.

In steel mills, power plants, and throughout industry . . . wherever superior performance is *expected,* owners enthusiastically recommend Bedford Cranes.

Available in all types and sizes . . . from five tons to 350 tons and up . . . for all kinds of indoor and outdoor services . . . each Bedford Crane is individually engineered and precision built for its specific application.

Built to the most modern standards and backed by more than 50 years of specialized crane building *and utilization* experience . . . Bedford Cranes have won fame the world over for advanced design and for safe, smooth, dependable performance.

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(Write for complete catalog describing Bedford Cranes in detail.)

STEEL MILL CRANES BEDFORD

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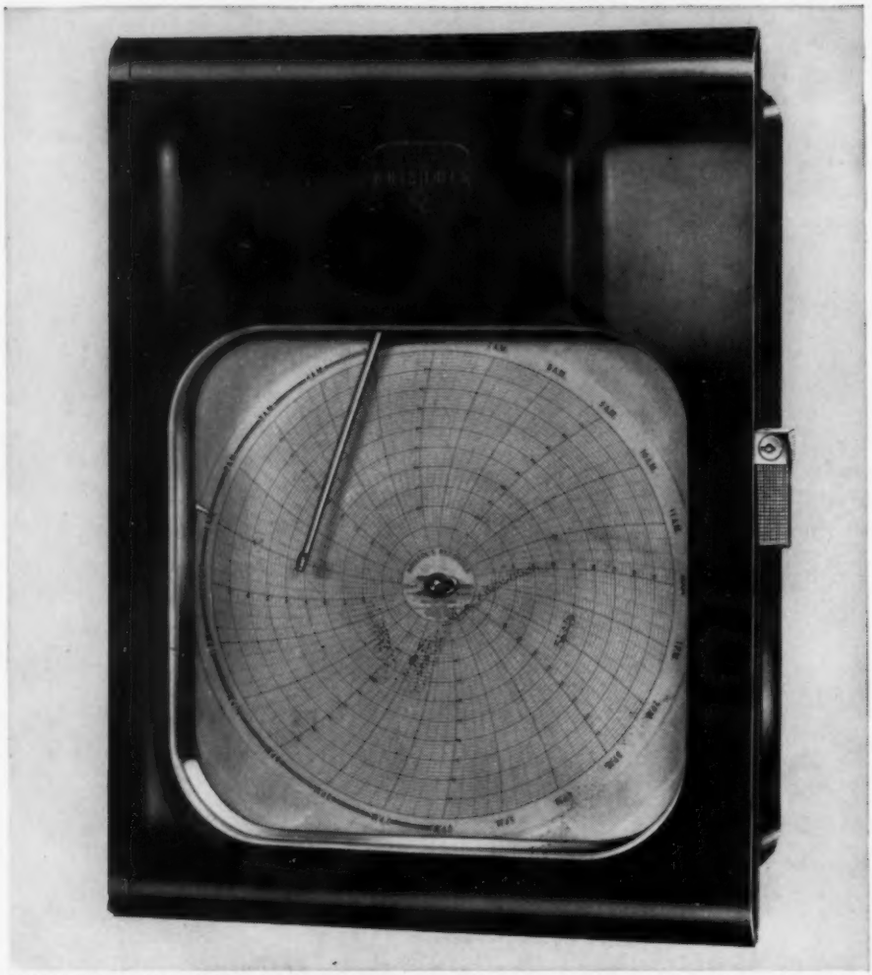

EASY-TO-USE BRISTOL RECORDING GAUGES come in pressure ranges from 0 - 0.2 inch of water to 0 - 10,000 psi. Vacuum gauges are available in various ranges from 0 - 30 inches of mercury and absolute pressure gauges in ranges as low as 0 - 6 mm mercury absolute.

Why are more Bristol recording gauges in use than all others put together?

• That's easy — accuracy and dependability are the reasons.

For accuracy, Bristol's measuring elements are unsurpassed. They are the product of 65 years of research and development. Bristol engineers are constantly engaged in developing pressure and vacuum measuring elements of higher accuracy, greater sensitivity, and increased stability.

As for dependability, many Bristol gauges have been in constant operation for more than 40 years — without special attention of any kind!

You can get the Series 500 gauge in models designed for recording, controlling and telemetering. Write today for free 32-page Bulletin G621. The Bristol Company, 123 Bristol Road, Waterbury 20, Conn.

Many ranges carried in stock for immediate delivery

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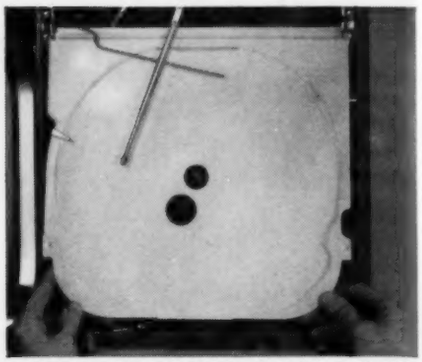
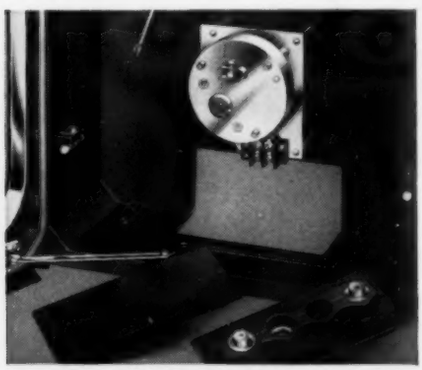


SNAP-ON TYPE CHART PLATE — No tools are needed to remove chart plate. Spring, finger release permits quick access to the space beneath the chart. Plate is easily replaced.



UNIVERSAL CONNECTION BLOCK — Mounting block for instrument connections easily changed from bottom to back of case or vice versa; measuring system can be removed or replaced.

PEN LIFTER — Simple, non-obscuring pen lifter, mounted independently of the chart plate, raises pen from the chart, provides complete freedom for working on instrument with chart plate removed.

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POINTS THE WAY IN HUMAN-ENGINEERED INSTRUMENTATION

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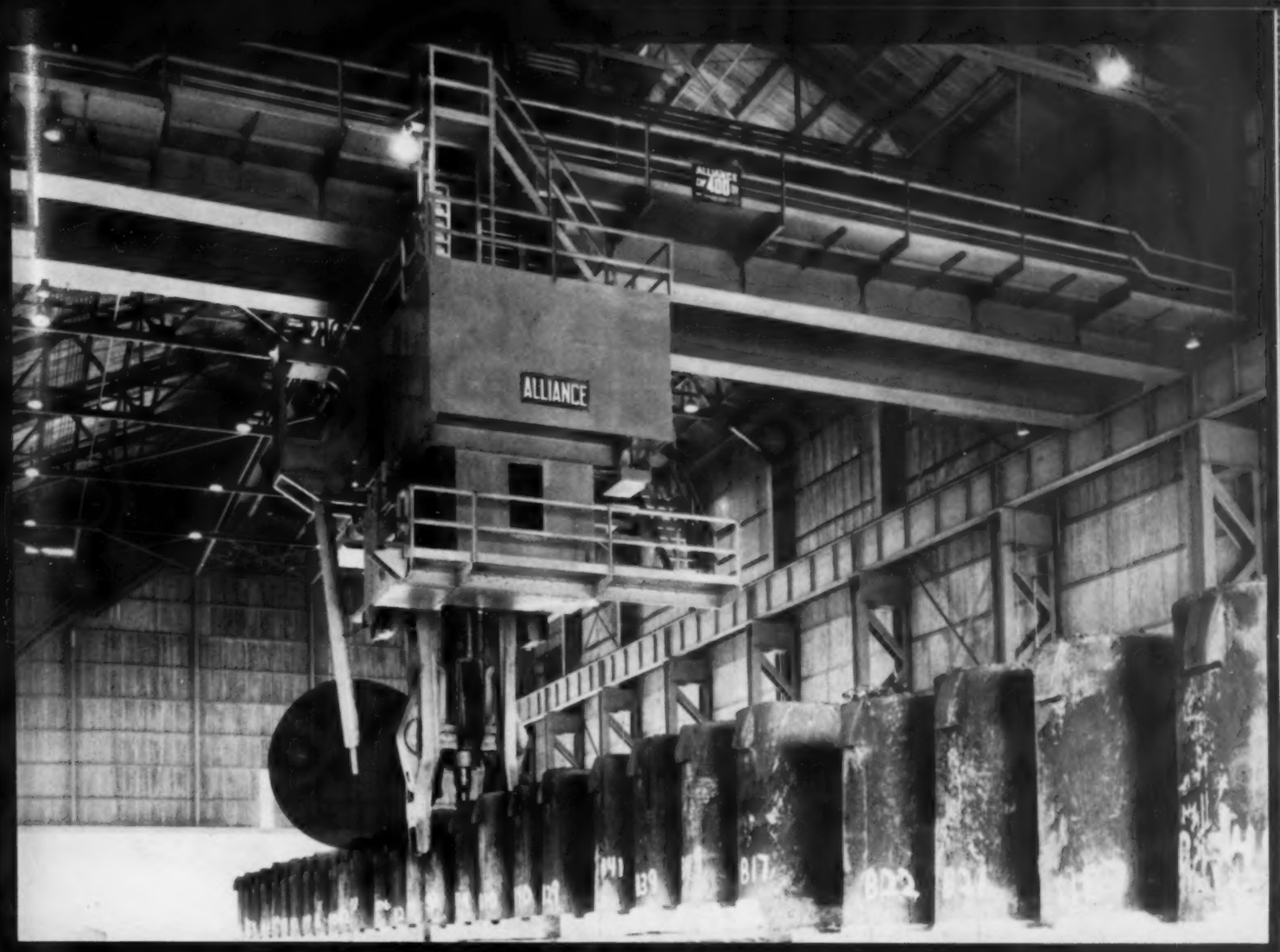

IMPACT STOOL LOOSENER

REDUCES WEAR ON STRIPPER CRANES

The big 400-ton Alliance push-pull Stripper Crane exerts 2,400,000 pounds' pressure to strip moulds from ingots cleanly and frees stool stickers at the same time. It's done with the patented Impact Stool Loosener. It reduces wear on stripper cranes, eliminates jiggling by crane, sends ingots to the mill ready to go . . . no need to loosen them with soaking pit cranes. The Alliance Impact Stool Loosener can be installed on any stripper crane. Big Alliance strippers, with a nameplate rating of 400 tons and overload rating of 1200 tons, embody many exclusive design features . . . a result of Alliance's knowledge of mill procedures and problems. Have Alliance analyze your lifting needs. A letter, wire or phone call brings the information you require.

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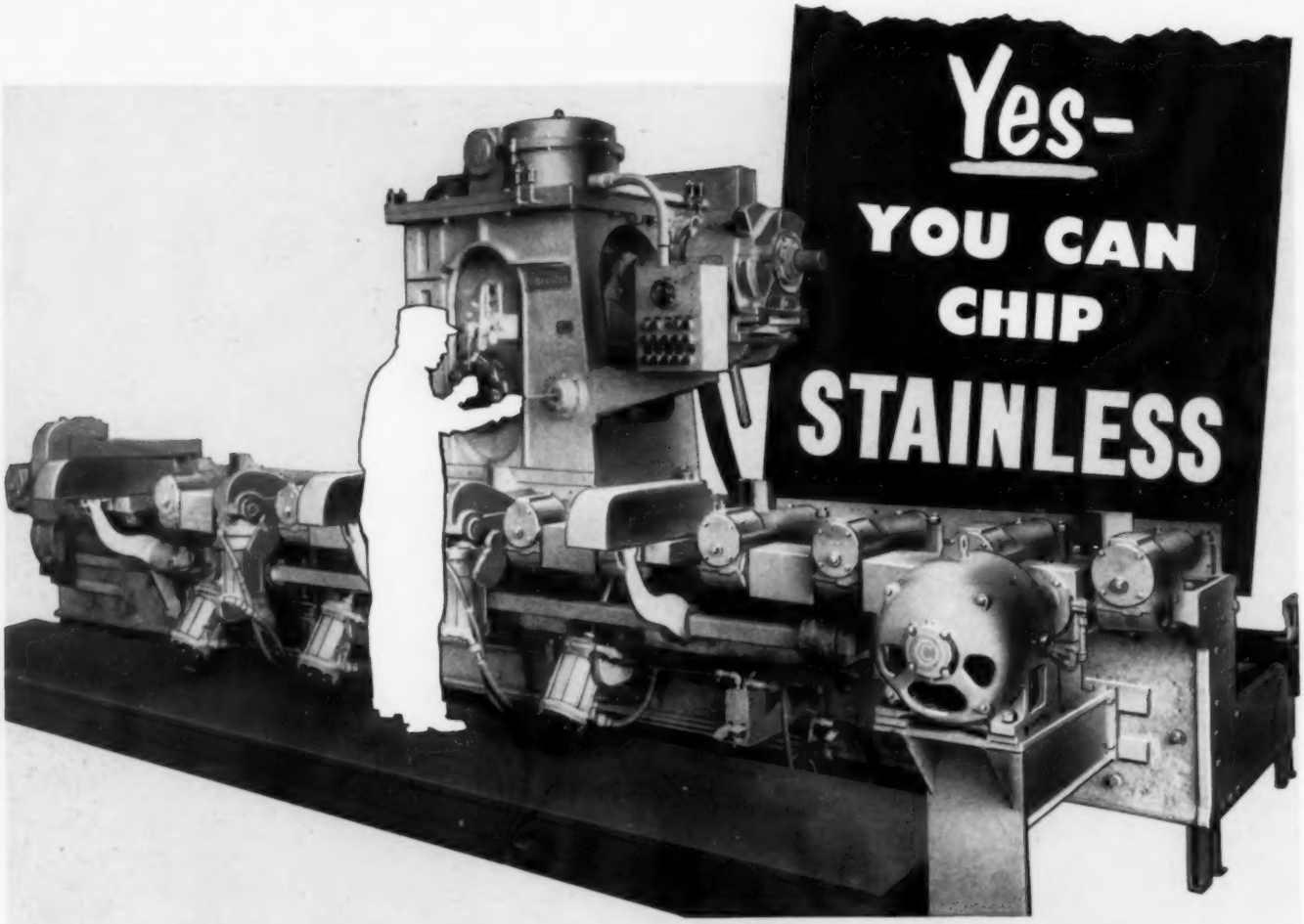

. . . and the Bonnot Billeteer easily handles other "Tough Babies" too!

Bonnot Billeteering is producing surprising results with stainless steel. While we are not inferring that the "highest-brinell rated" stainless is being chipped, *exceptional results are being consistently obtained in brinell classifications under 400.*

And when it comes to toughness, let's consider 52100 high chrome, high tensile steel that's always a problem to condition:

With a Bonnot Billeteer the operator completely skinned (full surface removal) *in just 8 hours,* 8 sides of 7" square blooms, 10' long plus 5 sides of 14" square, 15' long . . . *2900 square inches per hour with Bonnot Billeteering.*

Yes, steels of the toughest varieties—with or without annealing treatment—are being successfully chipped by the Bonnot Billeteer every day, everywhere in the industry.

If you still are struggling with laborious, dangerous billet conditioning methods it will pay you to find out about Bonnot Billeteering. A real investigation of production being obtained may surprise you greatly. Never a better time to find out—and never an obligation.

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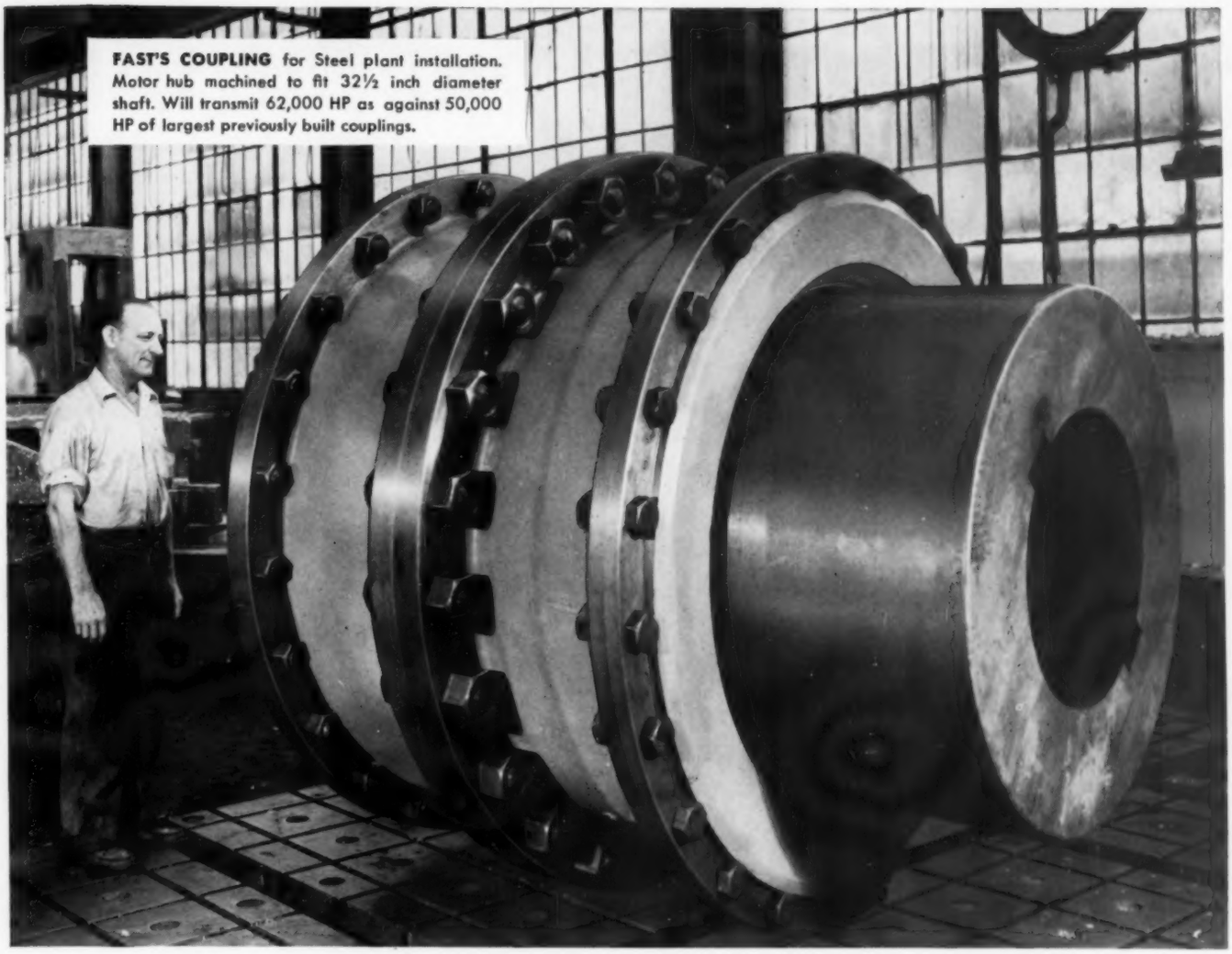

FAST'S COUPLING for Steel plant installation. Motor hub machined to fit 32½ inch diameter shaft. Will transmit 62,000 HP as against 50,000 HP of largest previously built couplings.

WORLD'S LARGEST INDUSTRIAL GEAR-TYPE COUPLING

To make a coupling that will transmit 62,000 HP and compensate for errors in alignment . . . that's more than a man-sized job.

But Koppers took on the project and this Fast's Self-Aligning Coupling is the result.

After six months of machining and assembly, this huge, *all metal* coupling is on its way to installation in a Milano, Italy, steel mill where it will carry power to a Mesta, 110-inch, four-high reversing plate mill.

It will transmit power from an electric motor to the equipment, and, at the same time, compensate for shaft misalignment and lateral float, give maximum power transmission efficiency, eliminate breakdowns and costly down-time.

WHAT'S YOUR COUPLING PROBLEM?

This mammoth Fast's Coupling is just one example of the outstanding jobs which Koppers is equipped to handle. 35 years of manufacturing "know-how" go into the production of *all* Fast's Couplings, large and small alike. Engineering specialists, experienced in designing Fast's Couplings for special applications, are well equipped to solve your coupling problems.

Remember, there's a Fast's Coupling for every power transmission application. Next time you have a coupling problem, call on Koppers . . . always ready to serve you. No obligation, of course. Also, for full details on Fast's Couplings for industry, mail this coupon.

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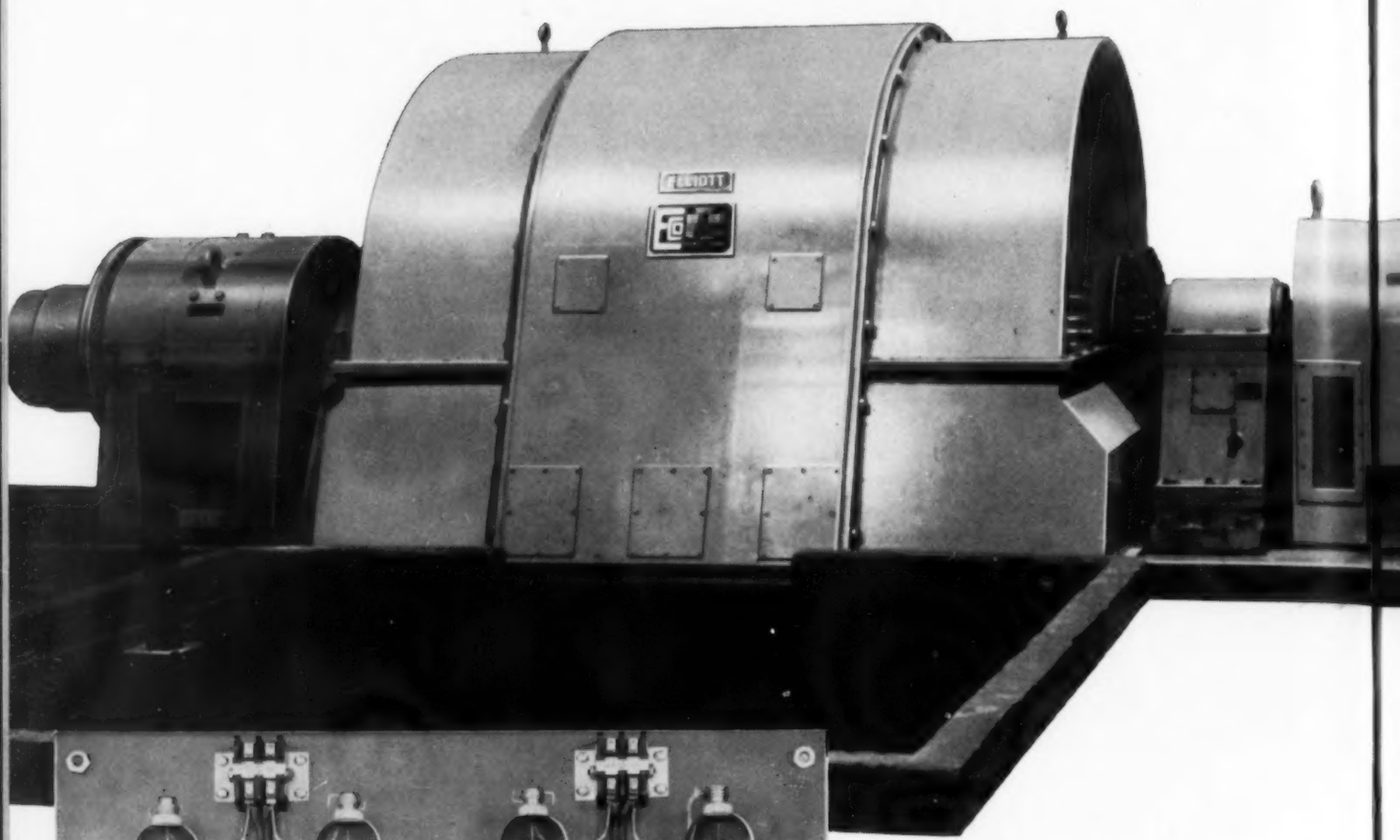
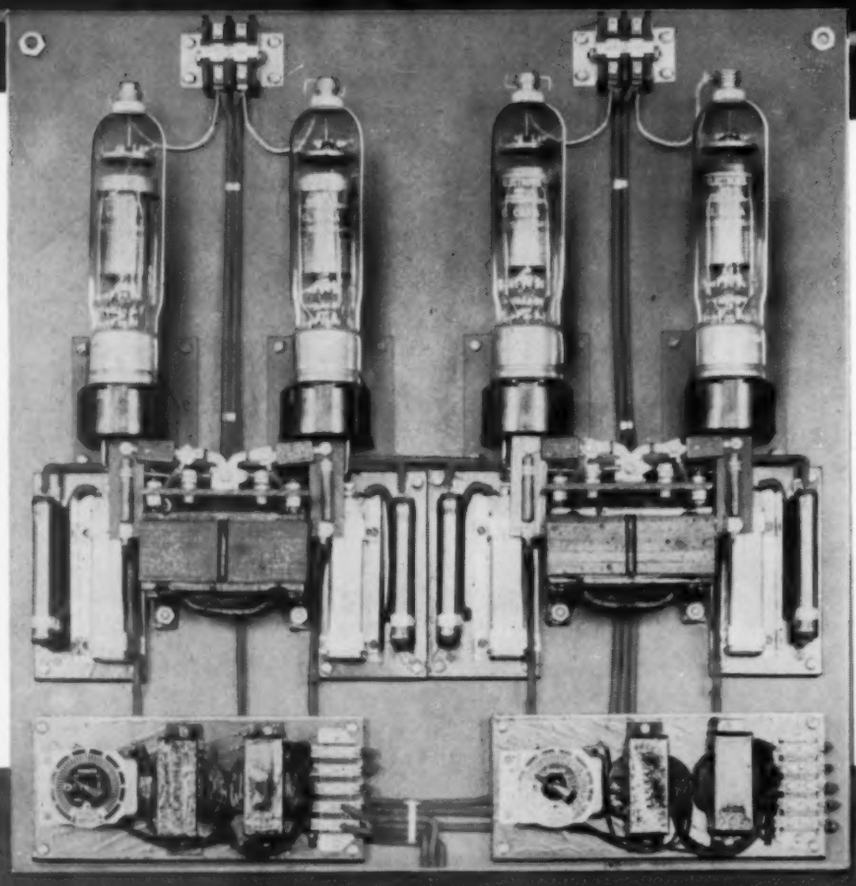
Smoothing out the rough





Shown above is the 20,000-kva, 900-rpm, 3-phase, 60-cycle, 13,200-volt air-cooled synchronous condenser installed at Owensboro, Kentucky, plant of Green River Steel Corporation. The direct-connected main and pilot exciters are self-cooled with filtered air inlets. The wound-rotor starting motor at the right end of the machine has a similar cooling system. Each bearing pedestal has an integral oil lift pump and oil circulating pump assembly, utilizing an oil-to-water heat exchanger. Cooling of the condenser itself is with an air-to-water heat exchanger mounted in a pit beneath the floor.

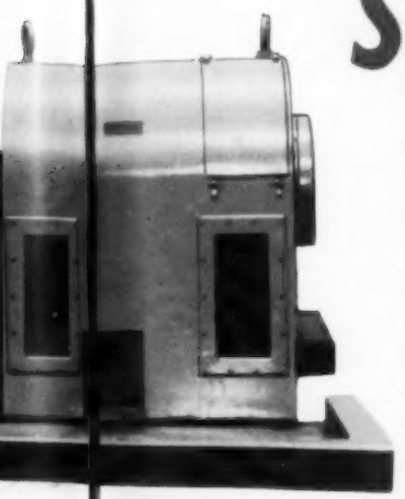
A high-speed voltage regulator of the electronic type was designed by Elliott Company to complement the low reactance condenser. Shown at left is a section of the regulator with grid-controlled, gas-filled tubes. All circuit components of the regulator were selected conservatively, with continuity of service and reliability of operation in mind.

STEAM TURBINES

MOTORS

GENERATORS

spots in electric furnace loads ...with an ELLIOTT Synchronous Condenser

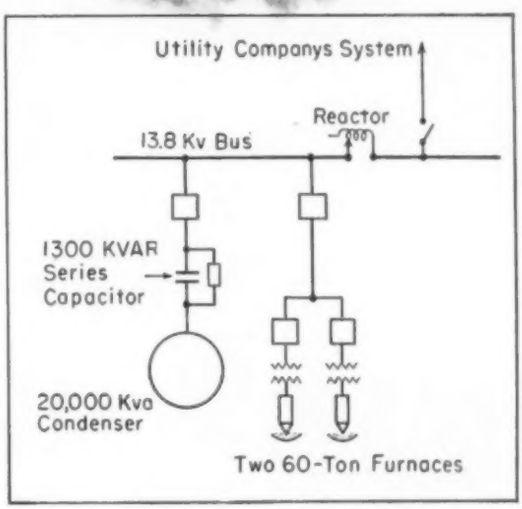


● Line current swings are violent and erratic during the meltdown period in an electric arc furnace. With a 60-ton furnace, for example, instantaneous current surges up to 2½ times full load are common. Such load fluctuation can result in a serious flicker problem for the supplying utility.

To avoid this, Green River Steel Corporation, Owensboro, Kentucky, has installed an Elliott 20,000-kva, air-cooled synchronous condenser in conjunction with their twin 60-ton electric arc furnaces. This condenser, which has the unusually low subtransient reactance of 21%, supplies leading KVAR . . . automatically . . . during surge periods.

A unique feature of the installation is the use of a capacitor in series with the synchronous condenser to provide maximum reactive output. Elliott-engineered control equipment insures full protection and instrumentation for the installation.

This simplified one-line diagram shows the arrangement of bus, capacitor, synchronous condenser, and electric furnaces employed by Green River Steel Corporation.



For complete details on Elliott synchronous condensers, air- or hydrogen-cooled, consult your Elliott representative or write Elliott Company, Ridgway, Pa.

Elliott FABRI-STEEL

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R4-9

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Take this husky Ohio Bolted Magnet, for instance. Heavy-duty strap-wound copper coils are protected by longer-lasting inorganic insulation carefully sealed with non-remelting or asphaltum compound.

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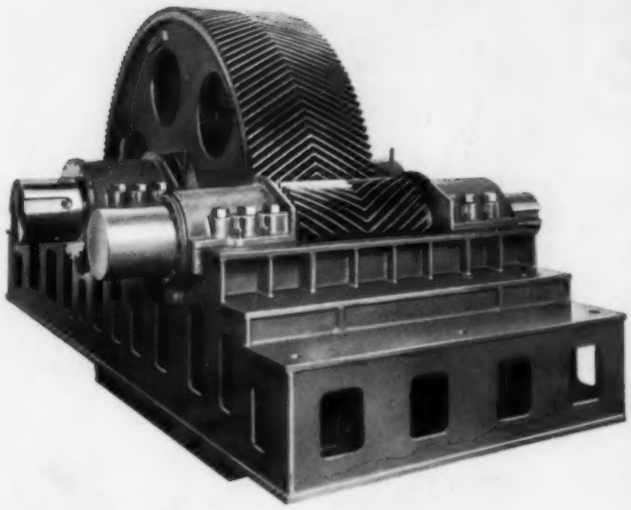
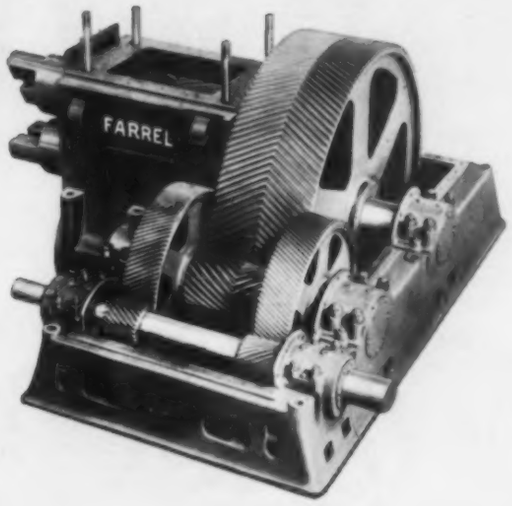


5500 HP

SINGLE REDUCTION UNIT

Herringbone-geared reduction unit designed to transmit power to a 134" three-high sheared plate mill, reducing motor speed from 375 to 70.35 RPM.



1000 HP

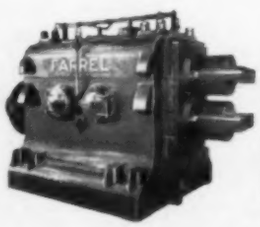
COMBINED DRIVE AND PINION STAND

Designed to transmit power to a two-high cold brass rundown mill. The first reduction gears are opposed single helical and the second reduction gears and the mill pinions are Farrel-Sykes continuous tooth herringbone.

150 HP

TRIPLE REDUCTION UNIT

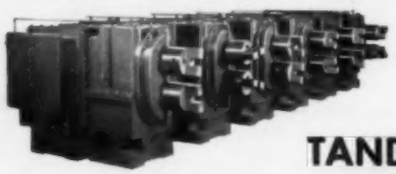
The three pairs of continuous tooth herringbone gears of this special tube mill drive provide a ratio of 113 to 1. A pinion unit is built as an integral part of the drive.



2000 HP

PINION STAND

21" pinion stand, designed to transmit power to a four-high aluminum sheet mill. The heat-treated, forged steel pinions are continuous tooth herringbone, generated by the Farrel-Sykes process.



TANDEM DRIVE

Transmits power from a single motor to six mills in tandem. Motor is connected to a herringbone gear reduction unit. Power is transmitted to the pinion stands through bevel gears mounted on a line shaft.

What do you need in a mill drive?

Do you need a single, double or triple reduction unit? Do you need a tandem drive, a pinion stand or perhaps a combination gear drive and pinion stand?

Whatever your requirements, no matter how unusual in design, size or capacity, Farrel will meet them. Each unit is individually engineered for the application.

Herringbone, single helical, or a combination of single and double helical gears may be furnished for gear drives. Mill pinions are usually herringbone type, although single helical pinions can be supplied. These gears and pinions are precision generated by the famous Farrel-Sykes process, assuring accuracy of tooth spacing, profile and helix angle, which results in high efficiency and smooth, quiet operation.

Send today for information on these designed-for-the-job mill drives. Or, if you prefer, a Farrel engineer will be glad to discuss your drive problems with you.

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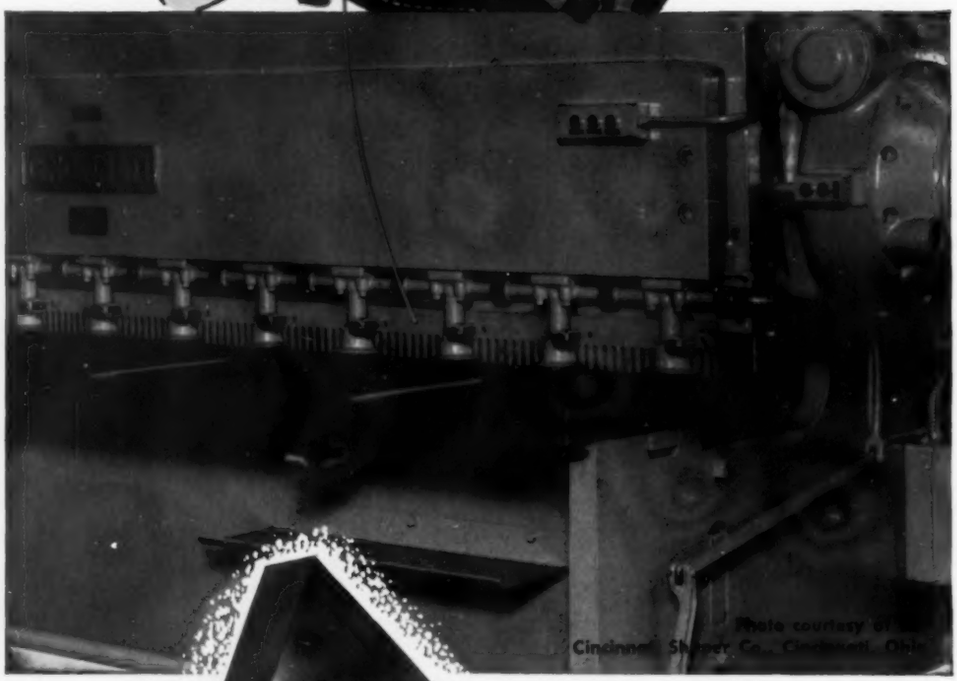
it's... OK let 'er go!



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Keep production costs down. Keep your machines running. OK Shear Blades run longer between regrindings . . .

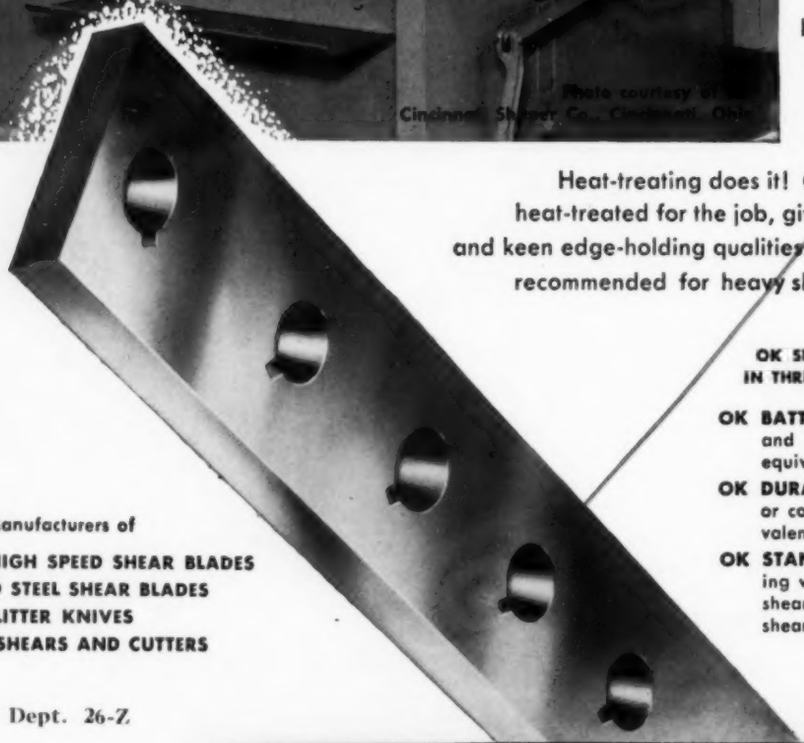
Heat-treating does it! OK Shear Blades are specially heat-treated for the job, giving them maximum toughness and keen edge-holding qualities. OK Shear Blades are highly recommended for heavy shearing and heavy plate work.

OK SHEAR BLADES ARE MADE IN THREE OUTSTANDING GRADES:

OK BATTLE AXE For shearing up to and including ¼" mild steel or equivalent.

OK DURA-CHROME For shearing hot or cold plate up to 1¼" or equivalent.

OK STANDARD For any type of shearing where only short runs or little shearing is done, and heavy plate shearing.



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Now... Bristol thermocouples with metal-ceramic protecting tubes

Bristol's new metal-ceramic LT-1 protecting tubes are the most important advance in thermocouple technology in years.

Combining the thermal conductivity and shock resistance of metal with the corrosion and oxidation resistance of ceramic materials, the new protecting tubes will last far longer than ordinary tubes, give you closer control and faster response.

Here are the advantages of the metal-ceramic LT-1's

- Resistance to combustion gases at temperatures up to 3100°F
- Resistance to oxidation in air at temperatures up to 2200°F
- Retention of strength at high temperatures – 1800 to 2500°F
- Greatly superior to most ceramics in resistance to thermal shock
- Resistance to attack by molten metals and furnace slag
- Increased sensitivity – the ⅛ inch wall has a high thermal conductivity

Get the whole story on Bristol's new tubes. Write for Bulletin P1261 today. The Bristol Company, 123 Bristol Road, Waterbury, Conn. 4.19

BRISTOL

Points the Way in Human-Engineered Instrumentation

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Superior
BLAST FURNACE COPPER CASTINGS

SMEETH-HARWOOD COMPANY
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In Canada—The William Kennedy & Sons, Ltd., Owen Sound, Ontario

Blast Furnace Copper Castings—also Brass and Bronze Mill Castings

LESS DOWN TIME...

when you CHANGE over to SPRAYING SYSTEMS descaling NOZZLES

If you want to materially reduce down time on rolling mills due to clogged nozzles, try Spraying Systems descaling nozzles. Large orifice diameter permits passage of practically all particles that ordinarily clog other types of nozzles. Spraying Systems nozzles produce an effective uniform flat spray, free of streaks, with an impinging force equal to over 96% of the maximum potential. Typical user is the Homestead District Works of U. S. Steel illustrated above. Nozzles are made of hardened stainless steel in a wide range of capacities and spray angles. Your inquiry is invited . . . write for Data Sheet 3997.

SPRAYING SYSTEMS CO.
3262 RANDOLPH STREET • BELLWOOD, ILLINOIS

Also write for Data Sheet 4516 . . . Pneumatic Atomizing Nozzles for direct spray gear lubrication.

Oil Immersed

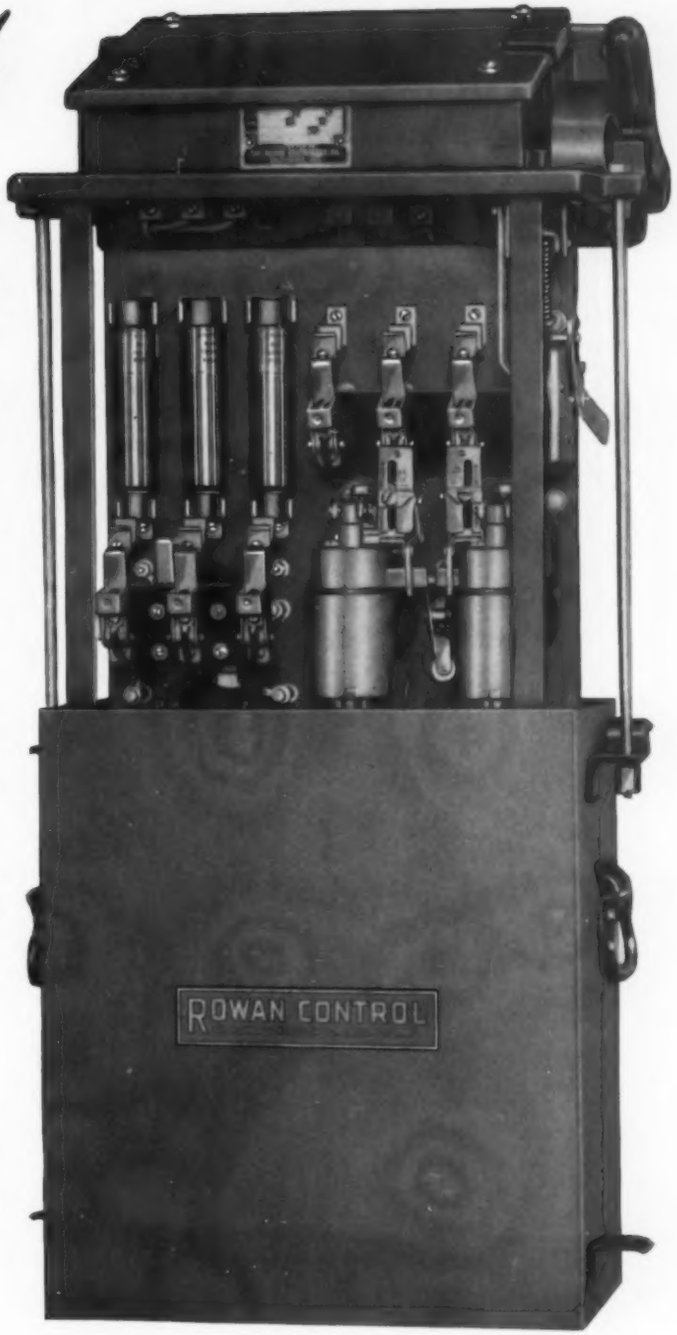
LOW VOLTAGE ACROSS-THE-LINE MOTOR STARTERS

Rowan Low Voltage, Across-the-line Motor Starters of the 780 Series are built to meet the requirements of NEMA Type XI and modifications are available for special applications. Their dependable performance under severe atmospheric conditions make them ideally suited for use in industries such as chemical plants, oil refineries, steel, cement and paper mills.

Incorporated in the 780 Series are such features as: easy access for inspection and maintenance; interchangeability of component parts with other starters of the same frame size.

Starters of the 780 Series are available in many combinations due to many variable components such as: safety disconnect switch, overload relays, Rowan AIR-SEAL fuses and wiring seal-off compartment.

A new booklet is available upon request which describes the 780 and other series of Rowan Oil Immersed Motor Starting Equipment up to 4600 volts.



Type 780 KBF, Frame 50

ROWAN CONTROL

Choose from 11 types of

Ohio Iron and Steel Rolls:

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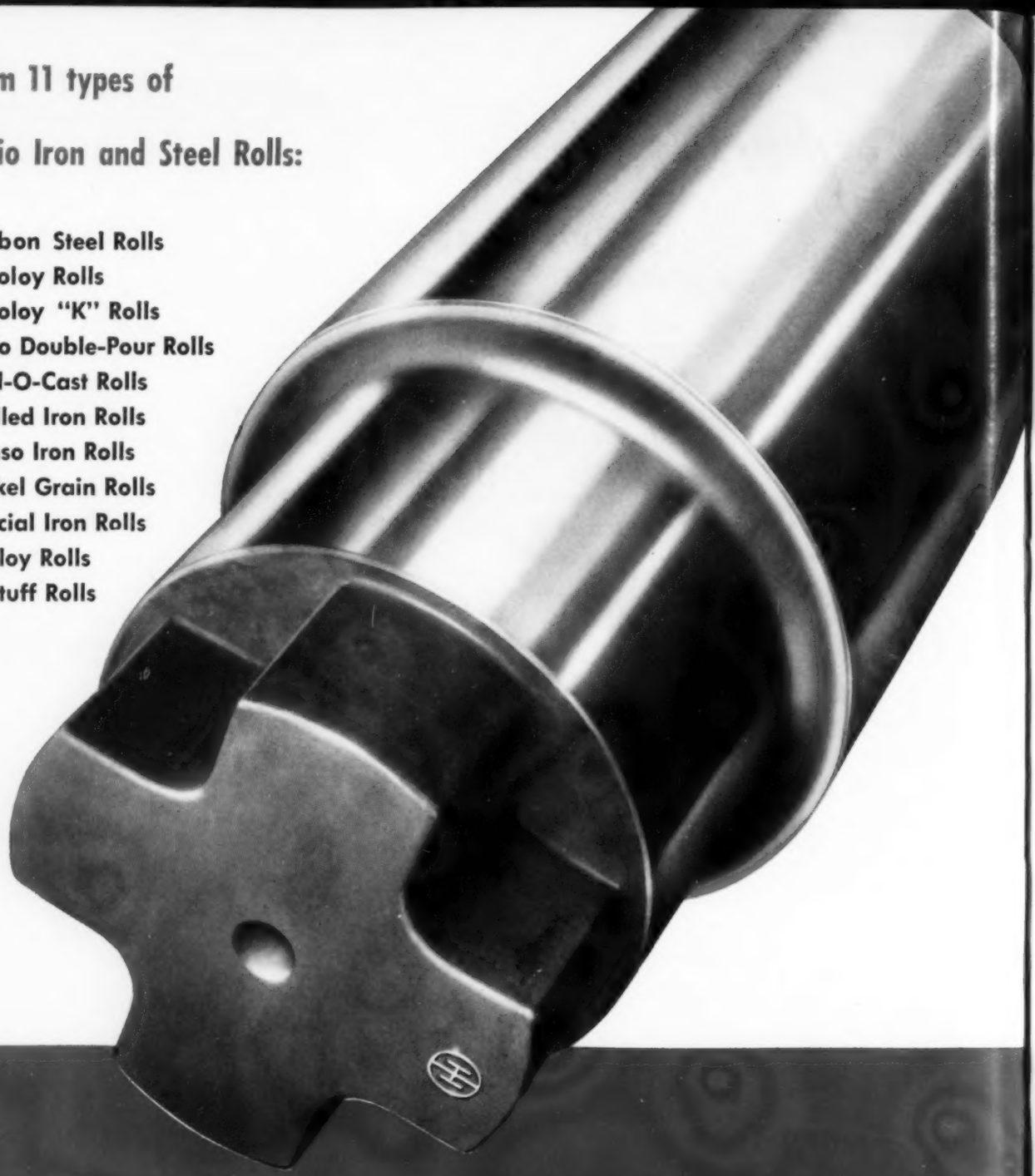
- Ohioloy Rolls
- Ohioloy "K" Rolls
- Ohio Double-Pour Rolls
- Holl-O-Cast Rolls
- Chilled Iron Rolls
- Denso Iron Rolls
- Nickel Grain Rolls
- Special Iron Rolls
- Nioloy Rolls
- Flintuff Rolls



Ohio Rolls

SHAPING METAL FOR ALL INDUSTRY

THE OHIO STEEL FOUNDRY CO.

SPRINGFIELD, OHIO

Plants at Lima and Springfield, Ohio

Industry News...

WATER CONSERVATION PROJECT TO BE BUILT BY ARMCO STEEL CORP. AT EAST WORKS PLANT

▲ Armco Steel Corp. will begin construction soon on a new $1,250,000 project at its East Works plant which will help greatly to conserve the water resources of the Miami Valley.

It is estimated that the new system will save more than 10 million gallons of water per day.

Armco pumps water from both the Miami River and from its own wells, and the water table in the Miami Valley area has been dropping steadily—due to months of dry weather and constantly increasing water usage.

The program calls for construction of an extensive new clarifying system to be used in connection with the present facilities at the East Works plant, an expansion of mill scale collecting basins, new pumping stations and sedimentation beds, and a great deal of additional piping to handle recirculated water.

The system will be coordinated with the city of Middletown's new sewer and sewage treatment program.

Armco has been working for many months on plans for the project. A special Armco committee was appointed in the summer of 1953 to study the water resources of the Miami Valley, and its recommendations are contained in the program.

All cooling water from the East Works bar and strip mills will be reclaimed, clarified, and reused in other areas of the plant. Some of the water will be recirculated over and over again in the hot strip mill.

Construction is expected to begin around July 1.

TIMKEN WILL INSTALL NEW ANNEALING UNIT

▲ A $278,000 continuous annealing furnace will be erected at the Gambrinus plant of the Timken Roller Bearing Co. to increase production of heavy walled seamless tubing. John Fick, vice president of the Timken Co.'s Steel and Tube Division, said that increased demand from the oil industry for heavy walled seamless tubing used in tool joints has made the new furnace necessary.

Research in the field, indicates that heavy walled seamless tubing can in many applications replace forged steel parts more efficiently and more economically.

Another substantial market for heavy walled seamless tubing is seen in the automatic transmission business.

Piercing steel is essentially a production forging operation, since solid bar stock is worked from both inside and out during the piercing operation and produces a high quality product for further fabrication.

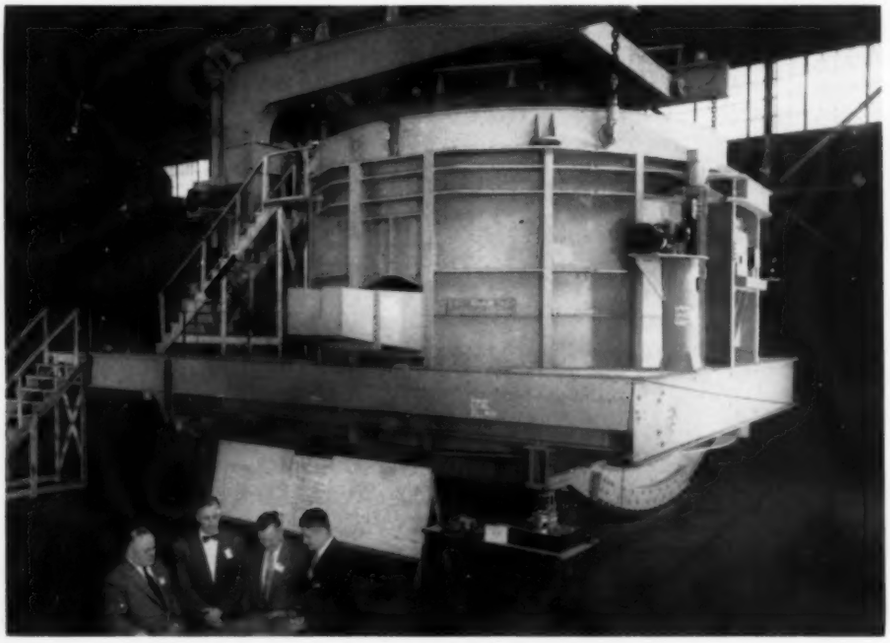
Measuring 175 ft in length and 6 ft 8 in. in width, the new furnace will be housed in a building 300 ft x 24 ft. Having a capacity of 3000 tons of annealed seamless tubing per month, it will be gas fired, and capable of using fuel oil in emergency situations.

The new annealing furnace will be charged and discharged by means of a fork lift truck. Thirty-two cars, 8 ft x 6 ft 8 in., will be moving through the furnace, with twenty-two cars in the furnace at one time. Five cars will be at the discharging end, and five cars at the charging end of the furnace at all times.

Completion is scheduled for late 1954.

ELECTRIC FURNACE BUILT FOR McLOUTH STEEL

One of the two 200-ton Heroult electric furnaces being made for McLouth Steel Corp. of Detroit, Mich. by U. S. Steel's American Bridge Division is pictured after completion at the Ambridge, Pa. plant. In foreground (left to right) are Oscar Seidel, Ambridge plant manager, Austin Paddock, vice president—operations of American Bridge, James R. Walsh, McLouth engineer and Norman Obbard, vice president and general contracting manager of the Bridge Division inspecting the furnace before shipment.



RADIOACTIVE PICTURE LOCATES BRIDGE "SWAY"

▲ By making radioactive pictures of the area where a "sway" had developed the Granite City Steel Co. recently saved itself the expensive, time-consuming job of dismantling part of its huge ore bridge to find a structural defect.

The St. Louis Testing Laboratories, which is licensed by the Atomic Energy Commission, made the radiographic pictures which pin-pointed the cause of the sway. The radioac-

tive material used was Cobalt 60.

Granite City Steel's electrically-driven ore bridge is a 450-ton structure used to handle coal, coke, limestone and iron ore. The ore bucket, suspended from the bridge truss, can handle 12 tons of material per load. The tracks on which the ore bridge moves extend from the coke plant to the blast furnaces, a distance of about 1600 ft.

Recently, Granite City Steel engineers noticed some movement at the connections between the top girders and the vertical members of the pier leg of the bridge. The cause of this movement or sway was hidden in the heavy girders and plates. The engineers could not tell without dismantling this part of the bridge whether the sway was caused by loose rivets, sheared rivets, fractured gusset (connection) plates, or a combination of these defects.

Granite City called on the St. Louis Testing Laboratories. A small capsule of radioactive cobalt was brought to the ore bridge in an 800 lb lead safe. In the capsule were three curies of Cobalt 60, a strong radioactive source. The capsule, about the size of a small automobile fuse, was suspended from a chalk line opposite the point where the movement or sway had developed.

Radioactive rays penetrated the layers of steel—the girders consist of a ½-in. web plate with 8 x 8 x ¾-in. angles at top and bottom; ¾-in. filler plates on each side of the web plate and between the toes of the angles; two 5/16-in. cover plates over the angles and plates, and a series of 6 x 6 x ½-in. vertical stiffner angles. The minimum thickness of the steel was 2⅝-in.; the maximum, 3⅝ in.

On the opposite side of the steel from the capsule of Cobalt 60 was a film to receive the ray picture. This process resembles the use of X-rays to study the interior of the human body.

The film showed the company that the sway was a result of certain rivets being loose. It was a comparatively simple matter to replace the loose, ¾-in. rivets with new ⅞-in. rivets. The ore bridge, is now stronger than ever.

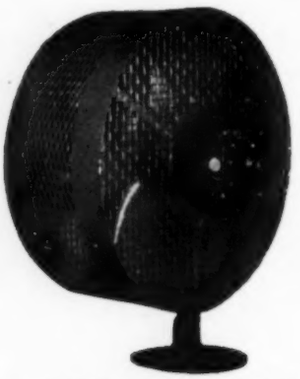
BEGIN CONSTRUCTION ON CONTAINER PLANT

▲ Construction of its third new plant to be started in the Delaware Valley in a little more than three years, was begun by U. S. Steel Corp., when John Hauerwaas, president of U. S. Steel Products division broke ground for a new container plant on a 27-acre plot just north of Camden, N. J. The event occurred just three years after ground breaking on the Bucks County, Pa. site of the Fairless Works, U. S. Steel's fully integrated steel plant and its National Tube division facility on the upper Delaware which were completed last year and are now in production.

The U. S. Steel Products plant will be completed early next year and is designed for the production of steel drums and pails for the petroleum, chemical, paint, food and other industries.

The plant will have approximately 300 employees and its annual capacity is scheduled to be 2,379,000

IS HEAT SLOWING UP YOUR WORKMEN?



TRUFLO CRANE CAB FANS
For cooling interiors of crane cabs and other confined areas. Adjustable both horizontally and vertically. Four blade type, 12 and 18 in. sizes.

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TRUFLO PORTABLE COOLING FANS
Easily portable. Help keep efficiency high where work is hottest. 12 to 36 inch diameters.

Production suffers when workmen are overheated. Steps begin to drag, efficiency falls.

Now, when speedy production is vital, Truflo Fans can help keep your workmen on their toes. All Truflo Fans are designed and built correctly to put fresh cool air *in large volumes* exactly where it is needed. Perfectly-balanced shafts and blades give more air per h.p. . . . strong steel frames stand up longer under hard use . . . rugged wire guards protect men against injuries.

All of the following types can help beat the heat, keep production moving in your plant. Write for illustrated literature.

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CRANE CAB FANS • WALL FANS
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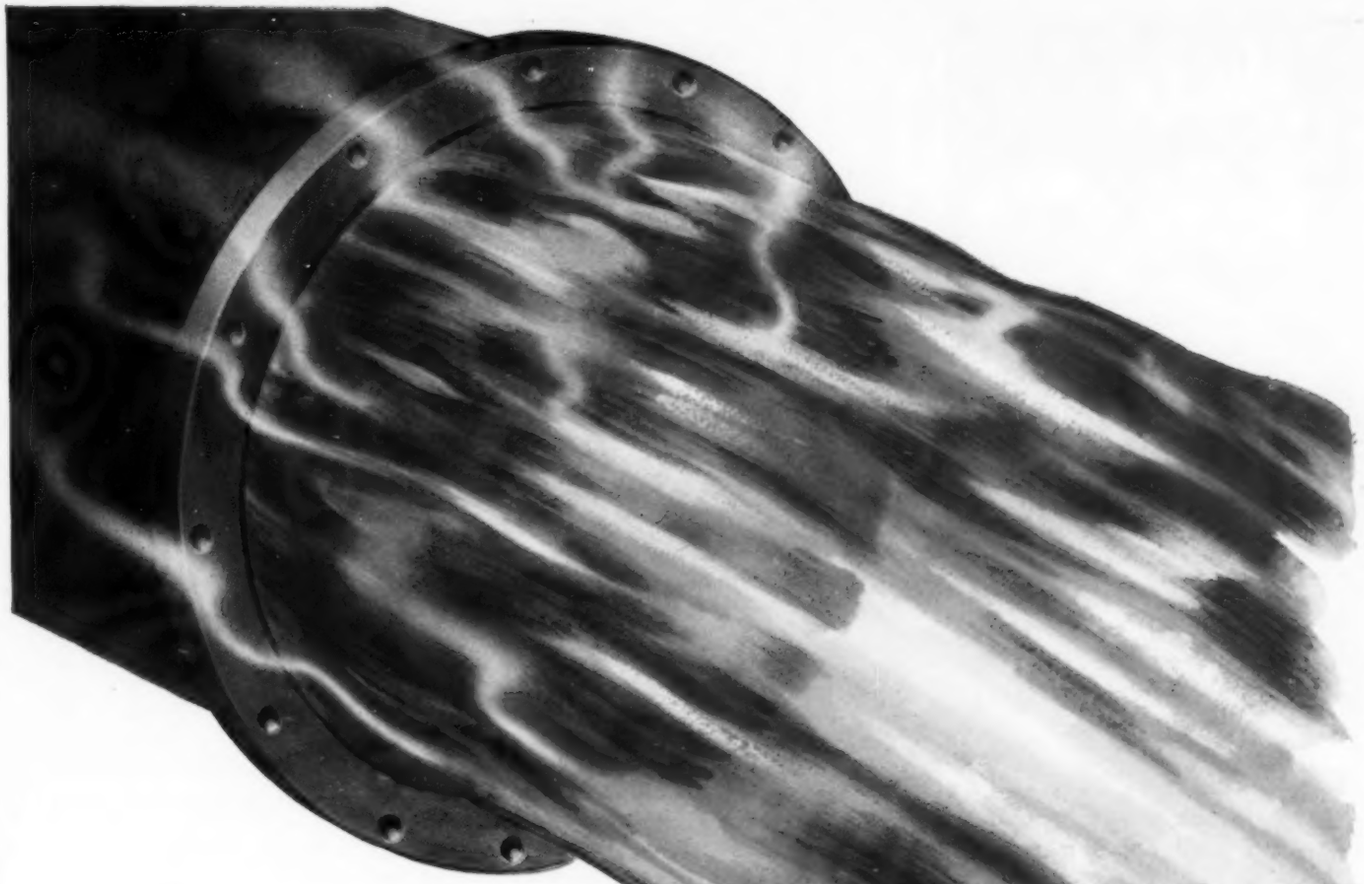
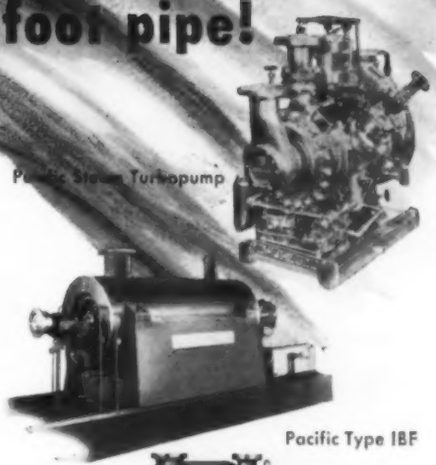


It takes a lot of water to fill a 7-foot pipe!

To bring the hot water to all the Pacific Boiler Feed Pumps placed in operation in 1953 would require a pipe 7 feet in diameter...

Today practically all of the large power generating companies throughout the United States have one or more Pacific Pumps in feed water service. Pacific Boiler Feed Pumps now operating include small vertical type units handling 47,700 pounds per hour at 710 psig discharge pressure—to very large horizontal type units handling 800,000 pounds per hour at 2430 psig discharge pressure. Bulletins 106, 109 and 118 giving details available on request.

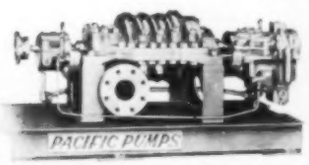


Pacific Steam Turbopump

Pacific Type IBF

Pacific Type ABF

Specify **Pacific CENTRIFUGAL BOILER FEED PUMPS**



Pacific Type JBF

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Export office: Chanin Building, 122 East 42nd Street, New York
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Hyde Park

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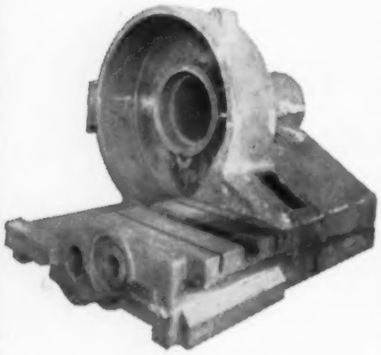
Gray Iron Castings

Castings of any size up to 80,000 pounds. Hyde Park facilities are equal to your every requirement



Machine Castings
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Hyde Park

FOUNDRY & MACHINE CO.
Hyde Park, Westmoreland County, Pa.
ROLLS
ROLLING MILL MACHINERY
GREY IRON CASTINGS

ANVIL BASE FOR DROP FORGE HAMMER

This anvil base for one of two 50,000 lb drop forge hammers being installed at Kropp Forge Co., Chicago, Ill., as part of the company's $5,000,000 expansion program, weighs 390,000 lb. The anvil is only one-third of the foundation required for each hammer. The foundation, which is 42 ft wide, 36 ft long and 23½ ft deep, will also include 5½ million lb of concrete with reinforcing steel. The entire installation, including the hammer and foundation, will weigh close to eight million lb.

drums and 3,200,000 pails which will be manufactured on production units including a 55-gallon high speed drum line, a combination heavy-drum line, a combination light-drum and grease-drum line and one high-speed pail line. Containers, chiefly for the petroleum and chemical industries, will range in size from 3½ to 7-gallon pails up to 100-lb grease drums and 55-gallon oil drums. Mr. Hauerwaas indicated that production of the oil drums will account for the largest tonnage of any one product fabricated at the new plant.

LESCHEN ROPE PLANS NEW OFFICE BUILDING

▲ Plans for the immediate construction of a modern, air-conditioned headquarters office for the Leschen Wire Rope Division, H. K. Porter Co., Inc., have been announced.

The new one-story structure will be built on the company's present property, with completion scheduled for June 1.

This is the latest step in the modernization program of the Leschen plant which has been underway for the past 8 months. With this new office arrangement operations will have been streamlined throughout for greater efficiency and economy of material flow and production.

AISE TO CO-SPONSOR HANDLING SESSION

▲The Association of Iron and Steel Engineers is co-sponsoring a session on materials handling at the semi-annual meeting of the American Society of Mechanical Engineers which will be held in Pittsburgh on June 20 to 24, 1954. Among the papers to be presented at this meeting is one on the "Use of Heavy Trucks in Industry," by F. W. Lamb. Another paper will cover "Shall It Be a Crane, a Conveyor, Or An Industrial Truck?" by A. T. Gaudreau.

All members of the AISE carrying membership cards will be able to attend any and all sessions of this ASME meeting without paying a registration fee.

Another session of this convention is being co-sponsored by the AMHS. Among the papers to be given here is one on the "Bulk Materials Stock Piling" by E. H. D. Gibbs, another on "Methods and Costs in Coal Storage with Scrapers," by D. K. Heiple

and a third on "Flow of Solids in Bulk-Handling Systems" by A. W. Jenikei.

WAGNER ANNOUNCES NEW WEST COAST LOCATION

▲ Wagner Electric Corp., announces a new location for its Los Angeles Calif., branch office and warehouse operations.

A new office and warehouse building will accommodate Wagner's automotive and electrical branch sales and service operations in southern Calif., Ariz. and part of Nev.

The modern new plant in El Segundo, Calif., contains 22,500 sq ft of floor space. It provides convenient parking area, modern truck handling facilities and a spur track for direct rail service.

Carl Stevens is manager of the automotive branch office, and L. G. Tandberg is manager of the electrical branch office.

RITTER ENGINEERING APPOINTED DISTRIBUTOR

▲ Appointment of Ritter Engineering Co. of 1515 West Liberty Ave., Pittsburgh, Pa., as a distributor for Parker Hoze-lok Fittings has been announced by D. A. Cameron, sales manager for the Parker Appliance Co. of Cleveland, Ohio.

Parker, which only recently announced quantity production on a newly expanded line of field-proved, Hoze-lok Fittings, is a leading manufacturer of precision hydraulic and fluid system components.

Ritter will serve the coal mining industry of western Pennsylvania and much of West Virginia, according to E. W. Hollis, manager of the Cleveland sales district for Parker.

The technical services of W. O. Murray, Parker Sales Engineer in the Pittsburgh territory will be available to the new distributor.

ARMCO PLANS EXPANSION AT MIDDLETOWN PLANT

▲ A $430,000 expansion of its fabricating division at Middletown, Ohio has been announced by Armco Steel Corp.

The expansion will add 32,000 sq ft of floor space to the facilities of the division, and will include additional equipment for producing the wide variety of fabricated steel products

NORTHERN

HI-LIFT CRANES

keep them rolling!

WHETHER handling strip, sheet, plate, structural steel or finished parts, a Northern Hi-Lift Crane helps keep your trucks and trailers rolling to make scheduled deliveries; handles big, heavy loads for fast loading; saves time, cost, and ruffled tempers.

For over fifty years Northern Cranes have consistently stressed three essential elements —safety, durability, dependable operation— with ample provision for meeting emergency demands under peak material handling conditions. They keep your production moving and your shipments rolling!

Write for our new Bulletin HL-115

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MAINTENANCE PROBLEMS

with **Plasteel** ROOFING and SIDING because

MICA* makes the difference

* *Tested and classified by the Underwriters' Laboratories and Associated Mutual Laboratories.*

Industrial case histories prove Plasteel reduces maintenance hours and costs to a minimum. Especially, in the steel industry where buildings are exposed to every conceivable corrosive atmosphere. Whether it is smoke, dust, acids, fumes, alkalies, or a combination of them, these harsh conditions are hard on buildings and equally hard on maintenance budgets. Such buildings need Plasteel — the only protected metal roofing and siding that gives you *Mica* protection. *Mica makes the BIG difference*—it prevents the protecting oils in Plasteel's asphalt-plastic coating from drying out. But that's not all . . .

Let our representative explain how Mica-Protected Plasteel can solve <u>your</u> maintenance problems

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MAIL THIS COUPON TODAY!

Plasteel

CORRUGATED SHEETS • ROOF DECK • INSULATED PANELS

that the plant turns out. The expansion should be completed during 1954.

Armco prefabricated steel buildings will be used throughout the expansion project.

A building will be erected on the site of one of the original buildings of the Central Works—Armco's first plant. The old building will be razed to make room, though some of its foundations and walls will be reused.

ANNOUNCES MOVING OF CHICAGO OFFICE

▲ Surface Combustion Corp. announces the moving of their Chicago industrial furnace division office from Room 1270, 122 So. Michigan to Park Ridge Federal Bank Building, 116 So. Prospect in Park Ridge, Ill.

CLEVELAND FIRM PLANS NEW PLANT FACILITIES

▲ The Electric Controller & Manufacturing Co. has awarded contracts for new integrated plant and office buildings on a 27 acre site in Cleveland, Ohio.

Main features of the structures are—greatly increased engineering and laboratory area to be fully equipped with testing equipment necessary for the company's expanding development program; 258,000 sq ft of manufacturing space on one floor where receiving, production, testing, and shipping layouts are designed to provide the flexibility and versatility needed for new and changing products; 50 ft by 50 ft bays, wide aisles, ample headroom, overhead traveling cranes and other mechanized equipment for low cost material handling.

Completion is scheduled for the spring of 1955. When ready for occupancy it is planned to move all Cleveland operations to the new location.

BLISS SHIPS HOT STRIP MILL TO FRENCH FIRM

▲ A complete hot strip steel rolling mill, believed to be the first ever shipped intact through the Port of New York, is scheduled for installation at Societe des Forges d'Hennebont in Morbihan, France. It took ten open-top freight cars to transport the complete mill from the E. W. Bliss Co. plant in Salem, Ohio, where it was built, to the New York port.

PICKLING ACID INHIBITOR.....

Trade Mark

RODINE

Reg. U.S. Pat. Off.

"Rodine" more than pays for itself in savings of acid and metal. More uniform pickling and better pickled surfaces are obtained when "Rodine" is used in acid pickling baths.

When sheet steel is pickled continuously, "RODINE" improves the surface and prevents "pickle burning" in prolonged pickling.

Photo by courtesy of
Kaiser Steel Corporation, Fontana Works, Fontana, California

CHEMICALS ACP PROCESSES

AMERICAN CHEMICAL PAINT COMPANY
General Offices:
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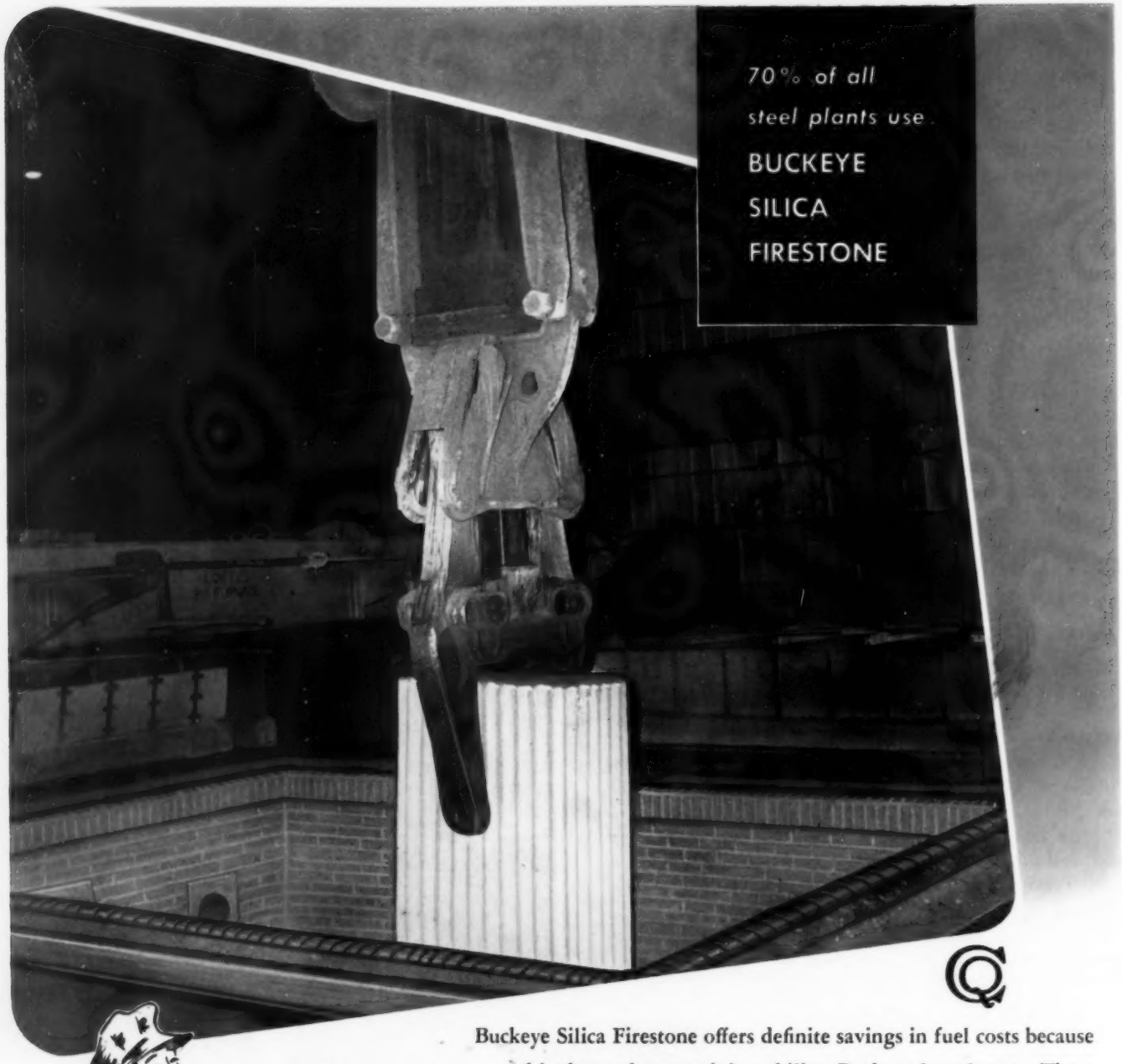

Buckeye Silica Firestone offers definite savings in fuel costs because of its better heat-retaining ability. Buckeye lasts longer. There is less need for repairs . . . down-time is at a minimum. Buckeye is the best buy obtainable per ton of ingot heated. You'll find a profitable difference between this natural refractory and other types in meeting the severe operating demands encountered in modern soaking pits. Join the 70% using Buckeye. Ask for a C. Q. engineer today!

THE CLEVELAND QUARRIES CO.
AMHERST, OHIO

Informative data of the many successful soaking pit installations of Buckeye is available for the asking. Tell us your problem and we will quickly suggest its solution – no obligation, of course!

BUCKEYE
"FOR THAT EXTRA SERVICE"
SILICA FIRESTONE

Technically known as a "Steckel-Type Two-high Universal Hot Mill," this unusual shipment comprises 45 large boxes or crates and six pieces of machinery mounted on skids, having a total gross weight of 340 tons. The largest single item weighs 21 tons.

This mill is destined for operation in producing hot rolled strip for sheets and tin plate at a maximum speed of 1000 ft per minute. It is unique in that it will produce hot rolled strip from ingots in a single heat to deliver the end product in coiled form.

According to George Perrault, Jr., Bliss sales manager of the Rolling Mill Division, "the mill and its component parts have been assembled complete as much as possible into integrated operating units ready for setting on the foundations at the French site, and include edging stand in addition to the horizontal pass mill. Electrical equipment for the mill is being supplied by French manufacturers under design specifications developed in collaboration with French and American engineers."

DISTRIBUTOR APPOINTED BY DIAMOND POWER

▲ Appointment of Graybar Electric Co., Inc., as national distributors of a new line of industrial television equipment, has been announced by the Diamond Power Specialty Corp.

Diamond will continue to build and to market the well-known "Utiliscope" line of industrial television equipment through its own branch offices, as in the past.

ANNOUNCE FORMATION OF STEEL SERVICE FIRM

▲ Formation of the Economy Steel Service Co., Chicago, Ill., specializing in the sale and precision processing of sheet mill and precision strip mill coiled steel, is announced. Jack Spear, formerly of the Metallurgical department, Weirton Steel Company, and for the past eight years connected with the steel warehouse industry in the Chicago area, organized the firm.

The new firm is fully equipped and staffed for the handling of precision slitting and edge rolling of narrow strip coils.

(*Please turn to page 186*)

You Can Make

3,000* Calls a Day

—BY EXHIBITING YOUR EQUIPMENT
—BY SEEING YOUR CUSTOMERS—PROSPECTS

at the 1954

IRON AND STEEL EXPOSITION

CLEVELAND AUDITORIUM · CLEVELAND, OHIO

September 28, 29, 30 & October 1

*Total attendance for four days of the Exposition will be 12,000 or more key executive and purchasing officials of the Steel Industry—your customers and prospects. You can see and sell 3,000 each day!

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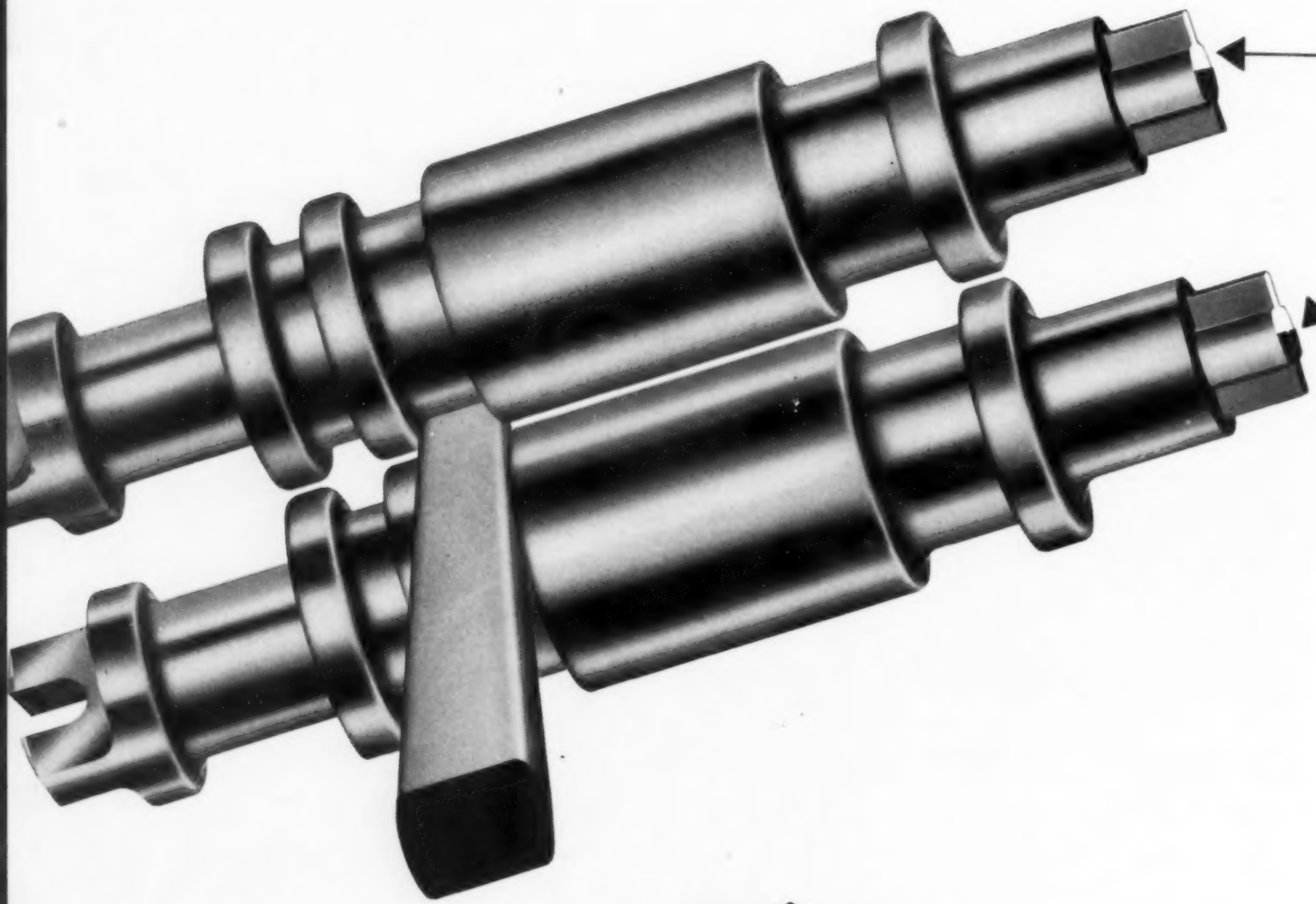
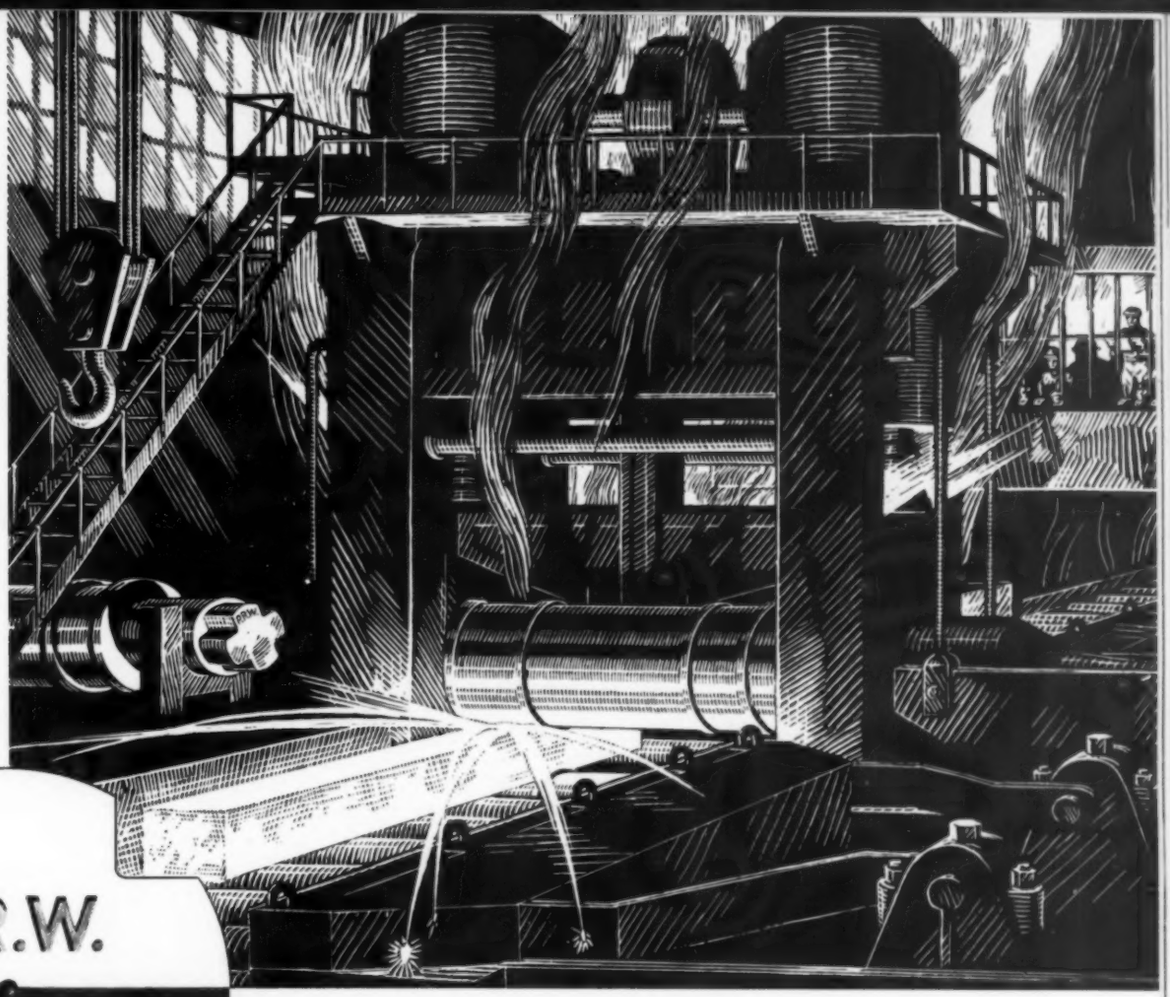
AMERICAN
SHEAR KNIFE CO.
HOMESTEAD • PENNSYLVANIA

"the right roll in the right stand"

. . . assures longer roll life



BLAW-KNOX



Our Rolls are color marked for specific applications

Our engineering services, for both design and application, are readily available to you . . . to assure satisfactory performance and longer roll life.

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BLAW-KNOX COMPANY • ROLLS DIVISION • PITTSBURGH ROLLS DEPARTMENT
PITTSBURGH 1, PENNSYLVANIA

(*Continued from page 183*)

Economy Steel Service Co. is located at 1832 West Irving Park Boulevard, Chicago, Ill.

FIRM MOVES LOCATION OF CLEVELAND OFFICE

▲ The Cleveland, Ohio office of Leeds & Northrup Co. has been moved to 1922 E. 107th St.

With 50 per cent more space than in the old location, the new office affords better facilities for providing engineering information and service to manufacturers, researchers, and educational institutions in northern Ohio and Northwestern Pa.

D. E. Moat is manager of the Cleveland office, and A. F. Moranty, with headquarters there, is the Leeds and Northrup regional manager.

SOUTHWEST STEEL ACQUIRED BY ARMCO

▲ Acquisition of Southwest Steel Products, Houston, Tex. by Armco Steel Corp. was announced by W. W. Sebald, Armco president.

Armco acquired all the common stock of the Steel Fabricating Co. as of the close of business March 31, 1954.

Southwest Steel Products produces fabricated reinforcing bars, bar joists, roof deck, and other products used in construction.

According to Mr. Sebald the main purpose in acquiring the company was "to develop and expand the bar joist business in the Southwestern part of the country."

Russell L. Jolley, president of Southwest, will continue actively in charge of the business which will be operated as a wholly-owned Armco subsidiary under the general direction of R. L. Gray, vice president of Armco.

HOUSTON SALES OFFICE OPENED BY DRAVO CORP.

▲ Opening of a southwest office at 1615 Blodgett Ave., Houston, Tex., is announced by Dravo Corp.

The Houston office will handle the sale of prefabricated steel and alloy piping for power plants, oil and gas transmission systems, refineries, petro-chemical and chemical plants, and other manufacturing processes on an FOB or delivered and erected basis.

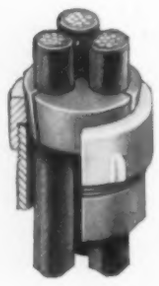
Additional items handled by this office are Dravo's complete line of oil and gas fired industrial space heaters and process drying equipment; crane cab and steel mill pulpit air conditioning equipment; and the division's construction services.

George R. Beidler, formerly of the Dravo New York office, has been appointed district sales manager.

COMPLETES INSTALLATION OF NEW MACHINE TOOLS

▲ Installation of approximately $3,000,000 worth of new machine tools in the East Chicago, Ind., and Wheeling, W. Va., plants of Continental Foundry & Machine Co. has been completed.

Among the new installations at the East Chicago plant are a 100-ton crane and an 84-in. draw cut shaper, capable of draw planing, push planing, milling, drilling and boring. A duplicate of this machine was also installed at the company's Wheeling works.



"Wedgelock"
Cable Supports and Seals

Complete range of types and sizes for all applications. Easy to install. Also combination support and terminators. Famous "Sali" Wedgelock inserts, tapered for locked grip. Quality construction. Competive prices.

Make Adalet YOUR headquarters for support fittings.

Write for Bulletin G-452a

THE ADALET MANUFACTURING CO.
14300 LORAIN AVE. CLEVELAND 11, OHIO

Give Long Trouble Free Service

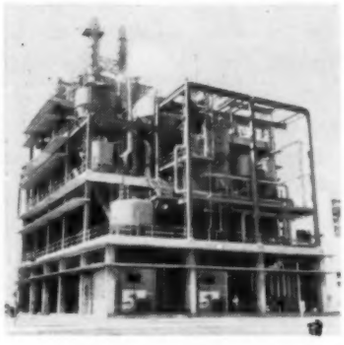
McDanel Porcelain Combustion Tubes and Zirco Tubes are precision made. Density, bore size, wall thickness, etc, are carefully controlled to assure maximum resistance to thermal shock, accurate fit and gas tightness. Cast as a single unit, they defy devitrification—give longer service and lower replacement costs. For carbon and sulphur determinations, McDanel Tubes are TOPS.

Refractory Porcelain Specialties in stock or designed to meet specific needs. Flasks, retorts, crucibles, etc. and parts "custom-made" to do the job.

Write Today for Catalog "McDanel Industrial Porcelains"

McDANEL Industrial PORCELAINS
McDANEL REFRACTORY PORCELAIN CO.
BEAVER FALLS, PENNA.

CORN AND RUST DON'T MIX



For solid corrosion prevention and vaporsealing tips write us for a reprint of the "Chemical Processing" article mentioned.

Many are the marvelous products made from corn at the Corn Products Refining Company's Bluebonnet Plant. It, too, like other industries in the area, has maintenance problems, for it is situated on the salty coast of Texas with its corrosive atmosphere. An article in "Chemical Processing" for January 1954 revealed that this plant has met its corrosion problem by coating nearly all steel structures and equipment with INSUL-MASTIC.

This same protection can be used in your plant. INSUL-MASTIC's *Superior* heavy asphalt coatings will stop moisture, acids, alkalis and other corrosive agents. They also vaporseal insulation, and a special, cork-filled coating will act as an insulation itself while it prevents rust. Steel mills, chemical plants, refineries and others are using INSUL-MASTIC for lasting protection. It's the rugged, heavy duty guardian of steel and insulation. Let us send you the name of your nearest applicator. Write today.

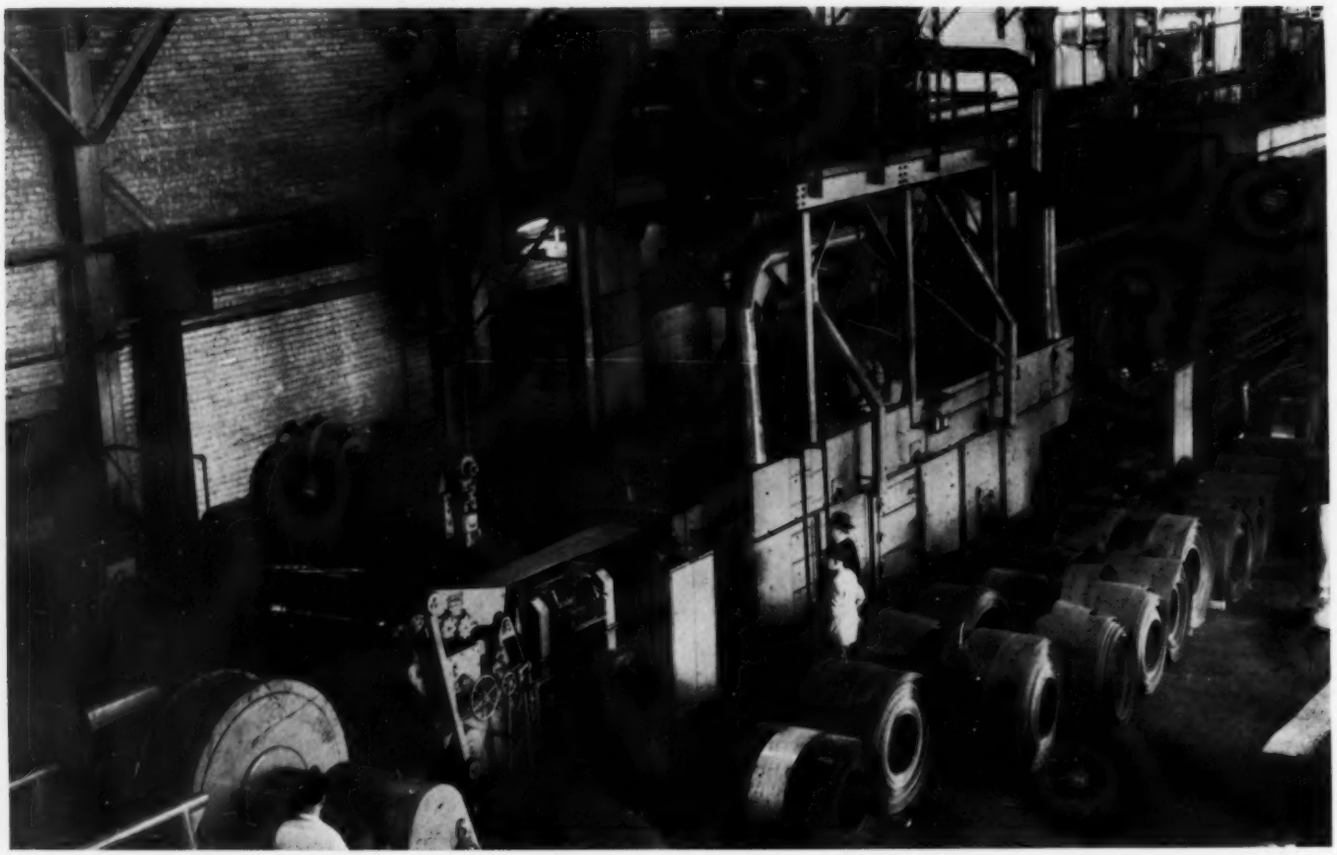
Insul-Mastic

think first of the coatings that last!

Representatives in Principal Cities

CORPORATION OF AMERICA • OLIVER BUILDING, PITTSBURGH 22, PA.

pioneering developments keep **WHEELABRATOR®** *first in blast cleaning*



Blasting Stainless Steel Descaling Costs

Allegheny Ludlum Saves Time, Money and Space with Wheelabrator Descaling

The cost of descaling hot-rolled steel strip and sheet has been drastically cut by mechanical descaling with airless Wheelabrator blast cleaning. At the West Leechburg plant of Allegheny Ludlum Steel Corp., stainless steel strip is descaled without scale breaking. It takes only five men to operate the Wheelabrator descaling line compared to 24 men for the batch pickling operation which it replaced. The Wheelabrator requires only 6,000 sq. ft. of floor space compared to about 10,500 sq. ft. for pickling. The loss of virgin metal has been virtually eliminated and the scale removed is in an easily recoverable condition. Reduction of acid consumption has simplified their acid disposal problem.

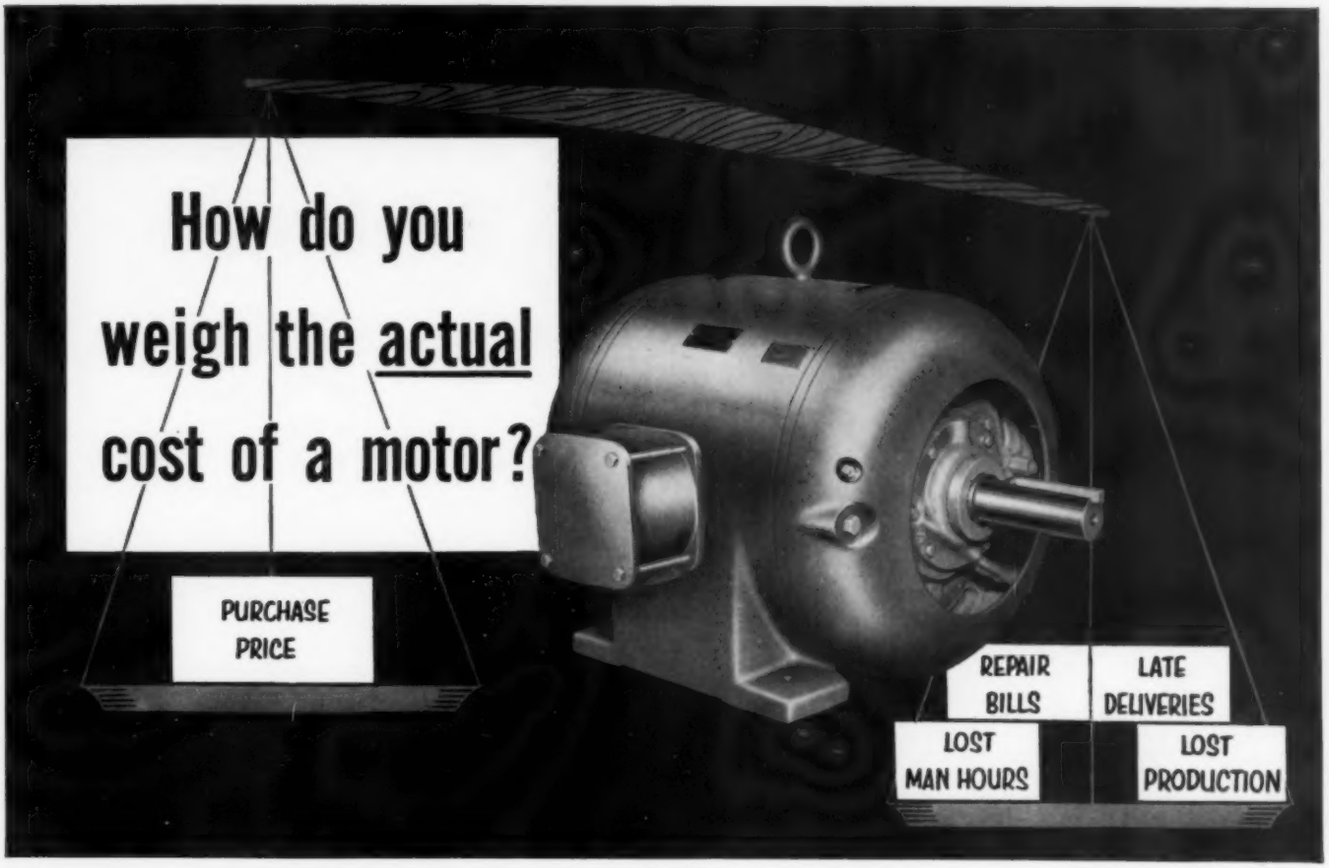
Steel is descaled through the controlled impact of Wheelabrator Steel Shot hurled by centrifugal force upon the steel surface to be cleaned. The constant, uniform flow of steel shot from the Wheelabrator units combined with the even, steady movement of the steel through the blast makes this mechanical cleaning method the most efficient descaling process yet devised.

Wheelabrator mechanical cleaning has been profitably applied to etching mill rolls and has effected unusual economics in cleaning strip, sheet, bar stock and skelp. Send now for complete details. Send for Bulletin 894 "How to Descale Steel Strip Mechanically" and Bulletin 914 "How to Descale Steel Sheet at High Speed and Low Cost."

Bulletin 894 tells how to descale steel strip at high speeds and low cost. Send for your copy today.

American
WHEELABRATOR & EQUIPMENT CORP.
396 S. Byrkit St., Mishawaka, Ind.

Wheelabrator®
AIRLESS BLAST CLEANING



Keep costs down...choose Wagner® Motors

The selection of the right motor for every specific industrial application is all important. Due consideration must be given to motor type, rating, slip, torque values, and other operating characteristics.

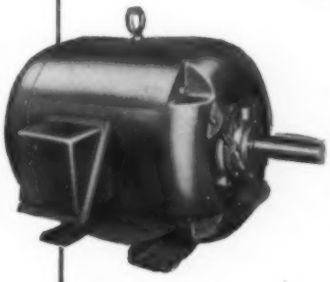
But, because the ultimate cost is the actual cost of a motor . . . alert buyers look beyond such specifications. They look for other factors, such as cool operation, with consequent longer insulation life . . . and they consider the *time-tested proven dependability* of the brand of motor they specify. They know that it's costly to take chances with motor drives.

Wagner Motors have been proving their reliability for more than sixty years. Many thousands of users throughout industry have found them a lasting investment in continuous troublefree performance.

The wide range of types and sizes in Wagner's complete line permits the selection of a standard motor for almost any need. Bulletin MU-185 gives full information.

Your nearby Wagner engineer will be glad to help you select the *right* motors for your next application. Call the nearest of our 32 branch offices, or write us.

Open type polyphase squirrel-cage motor for general purpose applications ... ¼ to 400 hp.



Totally enclosed, fan-cooled motor... explosion-proof or standard types... steel or cast-iron frame... 1 to 250 hp.

Wagner Electric Corporation EST. 1891

WAGNER ELECTRIC CORPORATION
6483 PLYMOUTH AVE., ST. LOUIS 14, MO., U.S.A.

BRANCHES AND DISTRIBUTORS IN ALL PRINCIPAL CITIES

ELECTRIC MOTORS
TRANSFORMERS
INDUSTRIAL BRAKES
AUTOMOTIVE BRAKE SYSTEMS— AIR AND HYDRAULIC

M54-17

Another

Koppers Service...

Coke-Plant Inspection

IT is of vital importance that regular examinations be made of coke ovens to assure minimum repair costs and maximum service life for the battery. Therefore, Koppers Company offers to the Iron and Steel Industry a complete coke-plant inspection service.

A coke-oven battery inspection by Koppers is a thorough checkup by experienced field engineers, followed by review and evaluation by men who have been designing, building and repairing coke ovens for many years. It does not replace, but complements the regular inspections made by your battery foreman or boss heater.

Because a Koppers inspector is not distracted by the daily problems of coke-plant operation, he can give objective and concentrated attention to the job with which he is concerned—inspecting a coke oven. From close up he makes a detailed visual examination of the oven chamber, right after pushing —while the battery is in operation.

If the inspection shows that repair work is needed, Koppers is equipped to handle that, too. We make recommendations, where applicable, and are completely prepared to fulfill all of your requirements regarding repairs that will prolong the life of your coke plant. An inspection, however, in no way obligates you to have the work done by us. We would welcome the opportunity to discuss our inspection service with you.

Constructing and repairing coke ovens is just one way in which Koppers serves the steel industry. For any kind of metallurgical construction, you can count on Koppers.

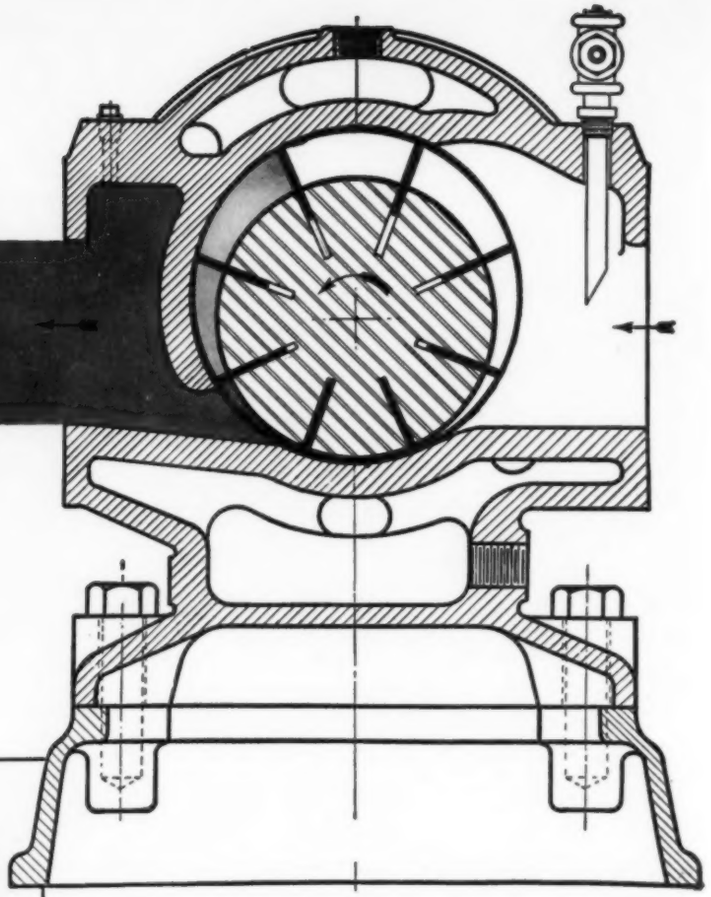
KOPPERS®

Engineering and Construction Division

KOPPERS COMPANY, INC., PITTSBURGH 19, PENNSYLVANIA

Inspector examining coke-oven chamber from the bench. In his book, he is making a careful record of all brick-work that should be repaired.

putting the SQUEEZE on compression costs



Check your needs for ● ● ● ● *Engine Starting Air* ● *Pneumatic Power*
Pneumatic Controls
Refrigerant Compression ● *General Plant Air*
Instrument Air ● *Air Lifts*

When you consider all the many uses you have for compressors—consider the best way to get compression with dependability, and minimum cost and attention.

Fuller Rotary Compressors have so many inherent advantages that they warrant your closest examination. Free from reciprocating parts, with no valves to leak or seats to grind, no unbalanced forces to set up vibration. Fuller Rotary Compressors assure low-cost, smooth-flow operation during their long life.

Check your own compressed-air needs and send this check list to Fuller. A Fuller engineer will give you the *right* recommendation to save you money. Write now to Fuller Company, Catasauqua, Penna.

Fuller **Pioneers of high-efficiency vane-type rotary compressors**

FULLER COMPANY
Catasauqua, Pa.

Branch Offices: Chicago ● San Francisco ● Los Angeles ● Seattle ● Birmingham

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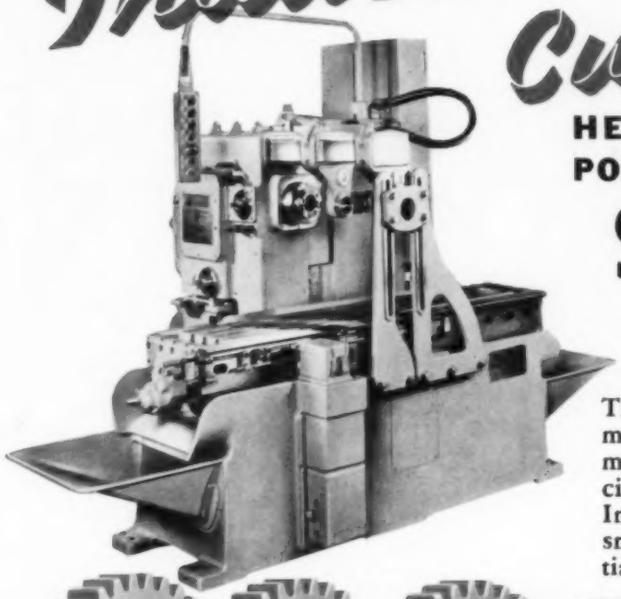
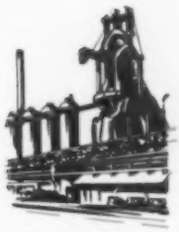
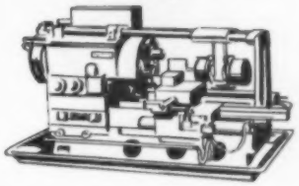
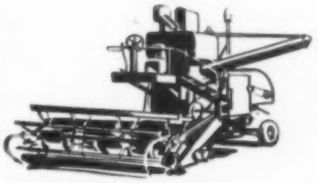
2078

Industrial Cut Gears







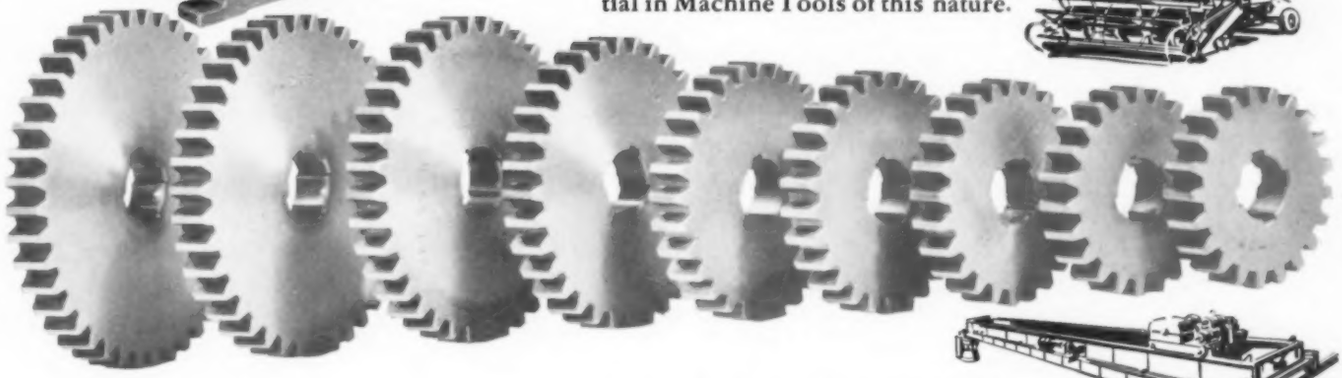


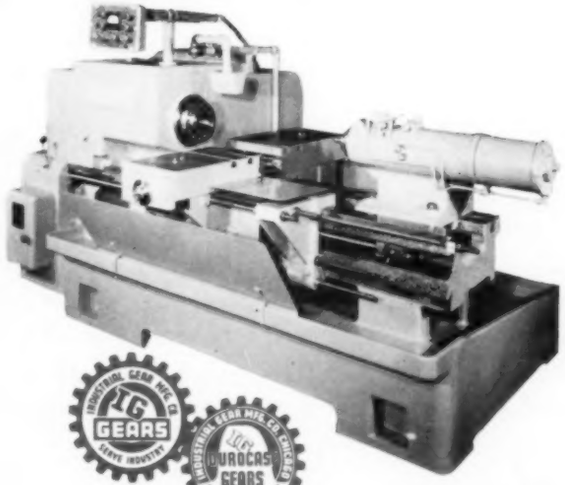
HELP TRANSMIT THE POWER THAT ENABLES

Sundstrand

MILLS and LATHES TO FUNCTION

The 'Nth degree of accuracy, is a must here. And, as these Sundstrand machines assure the highest precision in milling and turning so do Industrial Cut Gears provide for the smooth operation that is so essential in Machine Tools of this nature.

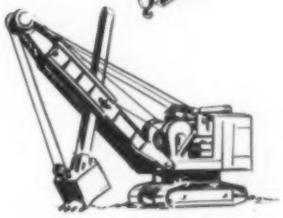


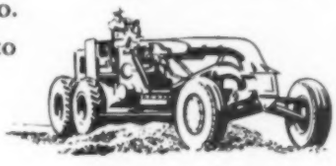


We are proud at Industrial to be factors in supplying Gears for so highly exacting equipment as is pictured here. It proves the worthiness of our product and the reliance users place upon us to meet their demands.

"IG Durocase" (Steel Mill type Gears) and "IG General Service" Gears are ready to serve you too.

May we have the opportunity to work with you?



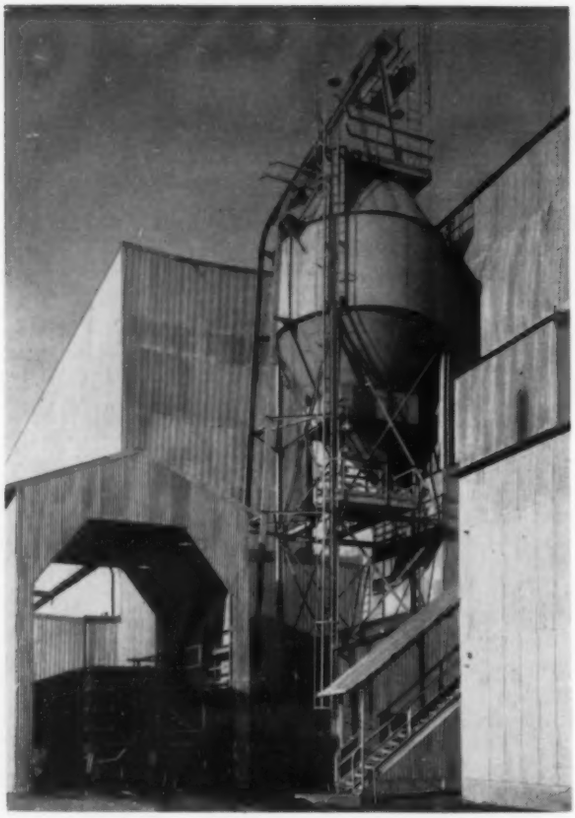


IG GEARS — SERVE INDUSTRY

DUROCAS GEARS — STAND THE STEEL TEST

Our plant, devoted exclusively to gear and sprocket cutting, can be visited pictorially through Bulletin No. 152-A. Write for your copy—and see how well equipped we are to handle your needs.

Industrial Gear Mfg. Co. 1527 W. VAN BUREN ST. CHICAGO 24 ILLINOIS



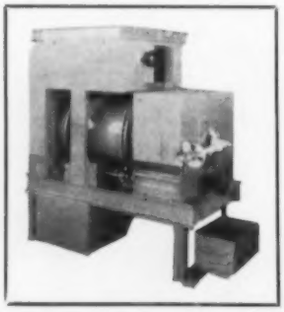
COKE BREEZE plant serving soaking pits at Fairless Works. Complete plant and equipment furnished ready for service by Roberts & Schaefer Co. on sub-contract.

COKE BREEZE ~SAND...

... are two of the materials for which R&S furnished plants and equipment for the Fairless Works. In each case the specific design utilized was dictated by specific requirements. The principles behind the designs have been tested and proved by R&S over a period of 50 years.

SAND dryer and storage equipment serving Diesel locomotives at Fairless Works. Equipment and accessories furnished by Roberts & Schaefer Co. on sub-contract.

WHAT BULK-MATERIAL HANDLING OR PROCESSING PROBLEM ARE **YOU** WORKING ON NOW — COAL, DOLOMITE, ORE, BY-PRODUCTS, SOMETHING ELSE? If it is hoisted, transported, stored or processed, there is a good chance that R&S engineering, fabrication and erection service can help you, whether your needs are for a complete new plant or modernization of present equipment.



R&S automatic drying-heating unit for granular crystalline material for production or pilot plant operation for the processing industries. (Installed at Fairless Works for drying sand).

ROBERTS & SCHAEFER CO.

Engineers • Fabricators • Contractors

130 NORTH WELLS ST., CHICAGO 6, ILL.

District Offices —
Pittsburgh, Pa. — Henry W. Oliver Building
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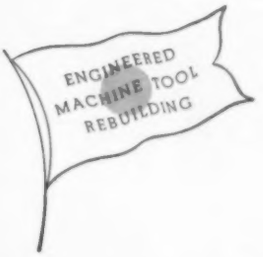
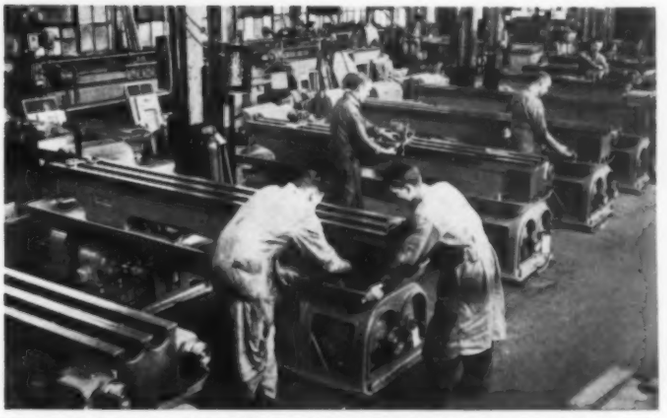
"Life Extension Institute" for Your Machine Tools



Speed was the problem here. As part of the Government machine tool re-activation program, Simmons has rebuilt over 400 machines. Shown in this bay (fore) are automatic screw machines, deep-hole drillers and various special tools. Despite this program, Simmons was able to continue its rebuilding for industry—thanks to its 120,000 square feet of plant capacity and diversified equipment.

Alignment of head and tail stock is part of the final test of this Landis grinder.

Sand blast facilities are maintained at Simmons to clean cast parts, remove inclusions.



Modernizing: To adapt these deep-hole drillers for carbide tooling, speed was doubled from 1500 to 3000 rpm; cooling system pressure was increased; heavier electrical equipment installed.

Rebuilding is the fastest way to get machine tools *today*. You will find that there are no long waits for delivery. *Engineered Rebuilding* guarantees user satisfaction. If you'd like to learn more about it, write for our quarterly, THE SIMMONS WAY.

SIMMONS MACHINE TOOL CORPORATION
1712 North Broadway, Albany 1, N. Y.

SIMMONS GIVES USED MACHINE TOOLS A NEW LEASE ON LIFE

Checking electrical systems is an important part of Simmons *Engineered Rebuilding*. Here, two technicians check a control panel on a rebuilt Cincinnati grinder prior to inspection.

Why has the steel industry invested in 108 NATIONAL CARBON TRADE-MARK blast furnace linings?

"National" carbon is found in more than 40% of this country's blast furnaces.

Why? Like any other investment by cost-minded steel producers, "National" carbon linings are bought on the basis of consistent, *proved* performance. Again and again, in over a hundred campaigns, "National" carbon linings have delivered:

- ***Consistently* longer life**
- ***Consistently* smoother operation (even during blow-in after bank)**

Here's the record: **31** "National" linings have *averaged* **2½** million tons per campaign. Of these, **18** have produced *more* than **2½** million tons and one is well over the **3¼** million mark. They're still going strong!

The term "National" is a registered trade-mark of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY

A Division of Union Carbide and Carbon Corporation

30 East 42nd Street, New York 17, N. Y.

District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

IN CANADA: Union Carbide Canada Limited, Toronto

NATIONAL CARBON PRODUCTS

BLAST FURNACE LININGS • BRICK • CINDER NOTCH LINERS • CINDER NOTCH PLUGS • SKIMMER BLOCKS • SPLASH PLATES • RUNOUT TROUGH LINERS • MOLD PLUGS • TANK HEATERS

Personnel News...

H. R. Ford has been appointed assistant chief plant engineer at Steubenville Works of Wheeling Steel Corp. **E. B. Murphy** was named assistant superintendent of the electrical department at Steubenville.

Arch J. Cochrane has been appointed manager of Chicago district operations for Youngstown Sheet and Tube Co., succeeding **B. M. Stubblefield** who has retired. Mr. Cochrane has been assistant manager for three years and had previously held responsible administrative and executive positions with other mid-west steel companies.

W. J. Thomas, general manager of the tubular products division of the Babcock & Wilcox Co., has been named a vice president of the company. Mr. Thomas has been with the company since 1932. He was associated with the boiler division of the company at Barberton, Ohio until 1941 when he left his position as assistant manager of the process equipment department to join the tubular products division. He was named assistant general sales manager in 1942 and general sales manager in 1948 and was appointed to the board of directors of the tubular products division in September 1952. He was made general manager of the division last August.

Clemens A. Tarter has been appointed assistant superintendent of cold reduction in the tin plate mill of Kaiser Steel Corp. Mr. Tarter brings 21 years of industry experience to his new position, having served with Republic Steel. He progressed from roller to superintendent of their cold reduction mill, serving at Republic plants at Warren, Niles and Cleveland, Ohio.

Thomas E. Millsop, president of Weirton Steel Co., has been elected president of National Steel Corp. He succeeds **George R. Fink** who has retired from active management, but will continue in a consulting capacity as chairman of the board of Great Lakes Steel Corp., and as a director of National Steel Corp. **Paul Carnahan,** vice president and assistant to the president of Great Lakes Steel Corp., was elected senior vice president of that company. **Elmer Schwartz** has been elected vice president in charge of operations of Great Lakes Steel Corp. He had previously been general manager of operations. **Earl M. Doig,** vice president of Hanna Furnace Corp., and of Great Lakes Steel Corp., has been elected president of the Hanna operation at Buffalo, N. Y.

J. M. Brashear has been named general superintendent of Lone Star Steel Co. Mr. Brashear was formerly open hearth furnace superintendent. **L. G. Graper,** vice president, research and development, takes on the duties formerly performed by **W. R. Bond,** vice president, operations, who recently resigned. **A. J. Malone** was appointed general superintendent of the steel division. **Glenn Anderson** was named assistant general superintendent, coke-iron-ore division. **Steve Purcell,** was appointed superintendent of the open hearth furnace department, and **McCready Young** was named superintendent of the production planning department.

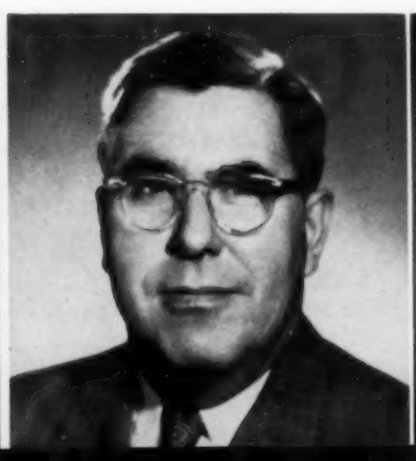
Robert E. Harvey was elected executive vice president and general manager of the Newport Steel Corp. In his new position Mr. Harvey will be responsible under **Louis E. Wolfson,** president, for over-all direction of Newport's operations. The elections of **Rolland O. Baum,** as a vice president of Newport Steel, and of **D. M. Pope** as comptroller of the company, also were announced.

Edward A. Livingstone, vice president of the Babcock & Wilcox Co., was elected to the board of directors of the company. Mr. Livingstone was placed in charge of the company's tubular products division. He takes over the position vacated by **Luke E. Sawyer** who became a consultant to the company handling special assignments in the tubular products division.

George V. Dutney has been appointed special assistant to the president of Nordberg Manufacturing Co. Mr. Dutney was associated with Jones & Laughlin Steel Co. in various capacities until 1920, when he joined Johns-Manville Corp. For the past 12 years, Mr. Dut-

H. R. FORD

ARCH J. COCHRANE



W. J. THOMAS

CLEMENS A. TARTER

ney has been on the Johns-Manville headquarters staff as manager of sales to the steel, non-ferrous and special industries. In his new position, he will be special representative of the president in sales and special public relations throughout the country.

G. P. Messenger was appointed superintendent of the iron and steel foundries of the National Roll & Foundry Co. Mr. Messenger was formerly chief metallurgist and research and development engineer with Kensington Steel Co., and more recently with Detroit Arsenal.

B. P. Finkbone, product engineer at the research division of Armco Steel Corp., received the fifth annual merit award of the Galvanizer's Committee of the American Zinc Institute at the group's annual meeting in St. Louis April 20.

Harold S. Geneen was elected vice president and controller of Jones & Laughlin Steel Corp. **A. A. Archibald** was elected vice president-special products and services.

George Bachman was appointed manager and chief engineer of the rolling mill and mill machinery division of Waterbury Farrel Foundry & Machine Co.

GEORGE BACHMAN

Dr. William J. Harris has joined the staff of Battelle Institute in Columbus, Ohio, as a consulting scientist. He comes to the research center from Washington, D. C., where he served for three years as executive secretary of the minerals and metals advisory board of the National Academy of Science and the National Research Council. At Battelle, Dr. Harris will serve in the office of the director in a liaison capacity between the Institute and its sponsors in government and industry.

Harold L. Heuser has been placed in charge of the sale of standardized conveyers in the Cleveland area for Mathews Conveyer Co.

H. Bigelow Moore has joined the staff of the Philadelphia, Pa., district sales office of the Reliance Electric and Engineering Co. as a sales application engineer.

Albert W. Erickson, Jr. has resigned his position with the Association of Iron and Steel Engineers, where he managed the Iron and Steel Exposition and publication advertising, to go with the American Decorating Co.,

ALBERT W. ERICKSON, JR.

Cleveland, Ohio. A graduate of the University of Pittsburgh School of Engineering, Mr. Erickson has been with AISE in various capacities since 1937, except for Army service during the war years. In his new position, he will engage in various phases of trade show work.

J. B. Sullivan has been appointed manager of the newly-opened Syracuse sales office of the Pennsylvania Transformer Co. Mr. Sullivan was formerly manager of the company's distribution transformer sales program.

David A. Griffith was named general manager of Allis-Chalmers Pittsburgh Works. Mr. Griffith has been assistant general manager at Pittsburgh for the last year. Prior to that he was assistant manager of Allis-Chalmers Washington, D. C. district office in charge of federal controls and regulations. He succeeds **J. W. McMullen,** who has been appointed vice president in charge of transformer and switchgear equipment.

Herman A. Gledhill, general superintendent of the Bridgeport, Conn., plant of Heppenstall Co., steel forgings manufacturer, has been appointed general manager of the Indianapolis, Ind., plant of Heppenstall Co. He was formerly general superintendent of the company's Bridgeport, Conn., plant. Mr. Gledhill started with Heppenstall in 1920 in the order department of the Pittsburgh plant. He served successively as heat treat foreman, night turn superintendent, tool supervisor, and superintendent. He was transferred to the Bridgeport plant in 1944.

Roy C. Andrews was appointed assistant to **Russell C. Stone,** director of industrial relations and personnel of Laclede-Christy Co. Mr. Andrews was formerly assistant personnel director at Rice Stix, Inc., St. Louis.

Vernon Barnes has been appointed to the sales application staff of C & G Sales & Engineering Co., manu-

Forged Hardened Steel Rolls

Available in any size...with any degree of finish required

BETHLEHEM FORGED STEEL ROLLS

are recommended for:

Cold-rolling of tinplate and ferrous sheets and strip

Running-down and finishing operations on copper and brass sheets

Hot- and cold-rolling of aluminum sheets

Cold-rolling of aluminum foil

Whatever your needs in forged hardened steel rolls, Bethlehem can meet them. All you have to do is tell us what you want; we'll take over from there.

Specifications on hardness, dimensions, and finish can always be met in full. Moreover, to satisfy delivery needs, we are equipped to do the job without delay.

On your where-to-buy list, mark Bethlehem as an always-reliable source of forged rolls. You'll find the Bethlehem product unsurpassed for the finest, "touchiest" work in your mill.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

New 1954 Booklet on

Aire-Rectifier Exclusive Features

• This new booklet illustrates the many exclusive features that make the Lintern Aire-Rectifier the choice of practically every steel and industrial plant using air conditioning on crane cabs and pulpits — features which assure unequalled cooling and filtering of the air at the lowest possible cost — features which have proven their worth in hundreds of applications while keeping maintenance costs at a minimum.

With this new booklet and Bulletin AC-533 you can select the right model Aire-Rectifier for the particular temperature range of the crane in mind.

Accompanying the description is a chart of applications (type of crane operation) temperatures encountered, and model recommended for the particular conditions.

By selecting the air conditioner of the proper size for the job, substantial savings are possible as compared with buying a unit designed for high temperature ranges when one for lower temperatures would answer the purpose satisfactorily.

Ask for Bulletins AC-544 and AC-533—yours free upon request.

THE LINTERN CORPORATION

Representatives in Principal Cities

ROUTE 20, EAST • PAINESVILLE, OHIO

facturers' agent in Milwaukee, Wisc., for the Reliance Electric & Engineering Co. In his new work Mr. Barnes will make his headquarters at 1012 N. Third Street, Milwaukee.

John H. Nelson has been named works manager of the Chicago, Ill. plant of Kropp Forge Co. Mr. Nelson, who formerly was assistant plant manager, joined Kropp Forge in 1948. Prior to that he was vice president in charge of forging production at Harvey Metal Corp.

A. I. Nussbaum has been appointed engineering consultant by the rolling mill division of Stanat Manufacturing Co.

Don Watkins has joined Continental Foundry & Machine Co. as a vice president with headquarters at the company's offices in Pittsburgh. Mr. Watkins has been

DON WATKINS

associated with the steel industry for over 30 years and has served in an executive capacity with a number of companies in the industry and in allied fields.

R. B. Young was appointed plant superintendent of the Sorel operation of Quebec Iron and Titanium Corp. Mr. Young was formerly with Bethlehem Steel Corp.

Edwin Ruh has joined Harbison-Walker Refractories Co. as a research engineer at the company's Hays Laboratory, Pittsburgh, Pa. He was formerly a research engineer at Rutgers University.

Raymond H. Blackford has been named vice president in charge of engineering of Durabla Manufacturing Co. Mr. Blackford joined Durabla in 1937, and was appointed chief engineer in 1945.

J. W. McMullen, general manager of Pittsburgh Works of Allis-Chalmers Manufacturing Co., has been named vice president in charge of transformer and switchgear equipment. Mr. McMullen will be responsible for operations at Pittsburgh Works and Boston Works and for all transformer and switchgear opera-

"*Fuel for the Furnaces*" by Agnes Potter Lowrie, famed artist daughter of a noted steelmaker. In this first of a specially commissioned fine arts series, Mrs. Lowrie finds beauty in weathered iron ore, creamy limestone, shaggy coke — basic elements so common most steelmen take them for granted. Limited edition of 15 x 18 color prints available. Complimentary copy sent upon request.

The Fine Art of Steel Making #1

For 60 years the history of American industry has been the story of steel. You know the landmarks. The old, slow hand mill. Table trains with their lusty offspring, the continuous strip mill. And more recently, the speedy, almost automatic four-high mill.

During these 60 years every forward step in steel production has been paralleled by an equal advance in Ironsides Gear Shield lubricants. Heavy duty Gear Shield, once hand-paddled onto exposed gears, is now formulated with a solvent for quick spray application.

With increased use of encased gears, Gear Shield was produced in liquid form for pouring, pumping or timed-jet application. As pressure on production increased, Ironsides was among the leaders in developing extreme pressure lubricants.

Today, so widespread is the acceptance of Ironsides lubricants that other makers often refer to their own products as "gear shields", even though Gear Shield is an Ironsides trade mark.

Ironsides is not mass production. We are the "custom tailors" of lubrication. Our special position is due in large part to our flexibility. We can — and do — formulate for individual applications and supply these formulas in any quantity from pails to tank cars.

We like tough problems, and we've solved a lot of them. For example, Palmoshield, replacement for palm oil and most important advance in lubrication since World War II.

If you have a special problem, we'd like to help you lick it. A letter or phone call will summon one of our research engineers. Address The Ironsides Company, Columbus 16, Ohio.

SHIELD PRODUCTS

Ironsides

By the makers of Palmoshield • "the palm tree that grows in Ohio"

Replacement costs take a plunge...when you use pickling baskets of corrosion-resistant Ampco* Metal

AMPCO Metal's high resistance to most corrosive pickling solutions means money saved for you. It means that pickling baskets stay on the job longer, when made of Ampco Metal. It means less time spent for maintenance, repairs, replacement. And Ampco Metal's toughness, coupled with its ability to withstand corrosion, means that you get long, low-cost performance all through your pickling line — from strip rollers, crates, chains, and yokes.

And there's more! Ampco Metal has remarkable wear resistance, and high impact and fatigue strength. It saves time, constant replacement costs, and expense in such applications as screw-down nuts, slippers, and flash-welder dies.

Let versatile Ampco Metal help you cut costs, improve production. Get complete details from your nearby Ampco field engineer or write us about your tough wear or corrosion problems.

*Reg. U. S. Pat. Off.

AMPCO ®

AMPCO METAL, INC. G-21

DEPT. IS-5, 1735 S. 38TH STREET
MILWAUKEE 46, WISCONSIN

West Coast Plant • Burbank, California

tions at Hawley, West Allis and Terre Haute plants. He will be located at West Allis Works. Mr. McMullen has a record of long experience in the transformer industry. He started with the Pittsburgh Transformer Co. in 1917, ten years before it was acquired by Allis-Chalmers. He was appointed assistant manager of transformer sales in 1935 and became assistant manager of the transformer section in 1945. Two years later he was appointed general manager.

Obituaries

Floyd L. Greene, former chairman of the board of General Refractories Co., died April 13. He was 65.

Paul F. Mumma, general superintendent at the Gary Works of National Tube division of U. S. Steel Corp., died April 16. Mr. Mumma, who was 54, joined National Tube in 1922.

Sam Keener, former president of Salem Engineering Co., died April 6 at the age of 66.

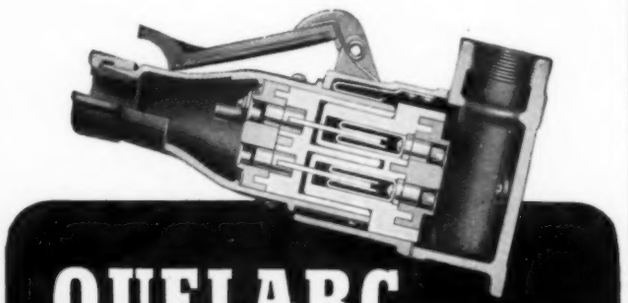
Cecil P. Folmar, electrical foreman at the Fairfield tin mill of Tennessee Coal & Iron Division, U. S. Steel Corp., died April 5. He was 64.

Bernard A. Schroder, president of General Machinery Co., died April 5.

Paul R. Canney, who was associated with Minnesota Steel Co., and later with American Steel & Wire Co., died March 20. Mr. Canney was a life member of the Association of Iron and Steel Engineers.

T. A. Brown, assistant to the general superintendent of the Fairless Works of U. S. Steel Corp., died May 1.

Charles W. Staacke, technical adviser on conveyor and belting sales for Hewitt-Robins, Inc., died April 9.



QUELARC The Circuit-Breaking Plugs and Receptacles . . . Ratings up to 200 AMPERES

The exclusive QuelArc construction provides exceptional protection to contacts, for safe use as current rupturing devices. Unique partitioned insulation provides extra long distance between contacts and between contacts and ground. Insulating chambers completely enclose all contacts and form an arc-trapping space. Galvanized cast metal housings, bakelite insulation and individually renewable contacts insure long service life. QuelArc plugs and receptacles are available in a complete range of styles, 2, 3 and 4 pole types—grounded through shell or extra pole. Housings with threaded cap, plain cap or hinged spring door. Ratings 20, 30, 60, 100 and 200 amperes, 250 volts DC, 600 volts AC. Consult your Pylet Catalog 1100, Bul. 1140-2 for complete listings.

SINCE 1897

CONDUIT FITTINGS • FLOODLIGHTS

THE PYLE-NATIONAL COMPANY

1383 NORTH KOSTNER AVENUE, CHICAGO 51, ILLINOIS

Call or Write STAMCO for...

Corrugating and Complete Line of Culvert Equipment—Slitting and Coiling Equipment for Ferrous and Non-Ferrous Material in All Capacities—Warehouse and Steel Mill Cut to Length Lines for Shearing and Levelling Sheets from Coils—Shears for Shearing Sheets and Plates Both Underdriven and Overdriven Types in all Capacities up to 1¼" plate.

STAMCO, Inc., New Bremen, Ohio

NEW *Aerovent* Portable Utility FANS

for product and personnel cooling • drying, exhausting and ventilating

Full 180° high-velocity air discharge. Mounts on ceilings, walls or floors. Heavy-duty rolled steel construction with expanded metal guards. Meets all safety standards. Available in sizes 16" to 36" for capacities to 20450 CFM

other models for every air-moving requirement

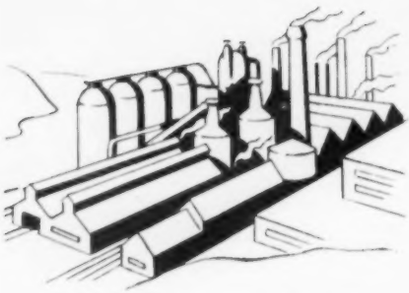
Certified Ratings

All Aerovent Fans are rated in accordance with the Standard Test Code and U.S.D.C. Comm. Std. CS178-51.

Ask for free folder P-50!

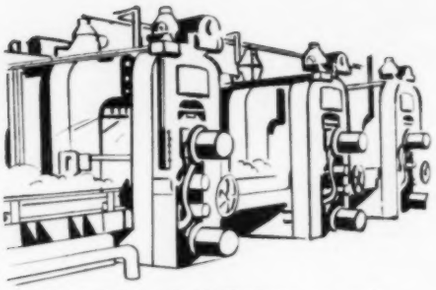
Aerovent Fan Company, Inc.

Ash and Brook Streets Piqua, Ohio

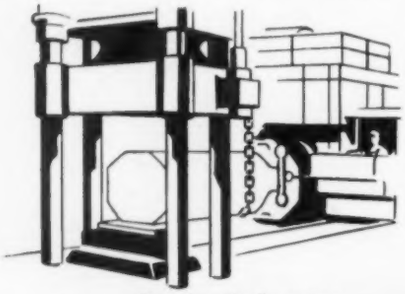


Steel Producing Plants

WHEN A *REGULAR LUBRICANT* ISN'T GOOD ENOUGH . . .



Hot Strip, Cold Reduction and Temper Pass Mills



Forging Industries

SPECIFY LEADOLENE* *Klingfast*

CHECK THESE 9 IMPORTANT FACTS:

1. **EXTREME PRESSURE pH-ilm STRENGTH** of 50,000 lbs. per square inch minimum by "Timken" testing machine.
2. **ADHESIVENESS** in which affinity for steel and other metals develops maximum adhesion and prevents drippage or creeping. Retains a flexible coating in nature.
3. **WATER REPELLENCE** which retards washing off, creates a lubricating pH-ilm under moisture or water conditions.
4. **CORROSION PREVENTION** is an excellent protective coating in that it will not etch or corrode metals. Is never acidic.
5. **COMPOUNDED STABILITY**—Will not bleed or change physical condition within range of higher than usual temperatures for this type of lubricant.
6. **LOW TEMPERATURE FACTORS**—While having a solidifying action by decreased temperature as low as —40 F., it does not harden, crack or decrease in adhesion. The flexible coating withstands distortion of the application.
7. **ABRASIVE RESISTANCE**—Extremely high for a lubricant. Does not wipe off nor will be removed in handling by workmen's hands or gloves. Is extremely repellent to adhesion of scale, metallics and other forms of dusts or contamination.
8. Klingfast has remarkable corrosive resistance to salt or sea water, acidic vapors and solutions.
9. Klingfast can be removed by ordinary solvents such as kerosene, gasolene, naphtha, carbontetrachloride and similar substances but is highly impervious to lubricating oils and greases.

The "I.P." LUBRICANT*

On the really tough jobs in the steel industry, the answer to vastly reduced lubricating costs and extended equipment life is *Leadolene Klingfast.* Capable of withstanding pressures up to 50,000 p.s.i., this lead-base lubricant with its "indestructible pH-ilm" has proved itself repeatedly on the most difficult applications.

For efficient lubrication in the presence of water . . . for extreme adhesiveness to steel under high heat conditions . . . for unexcelled abrasion and corrosion-resistance . . . for actual cash savings up to 400 per cent—investigate the performance characteristics of *Leadolene Klingfast.*

*I. P. . . . ("Indestructible pH-ilm" lubricant)

Write for 24-page descriptive booklet

THE BROOKS OIL CO.

Since 1876

Executive Offices and P ..... **Cleveland, Ohio**
Executive Sales Offices ..... **Pittsburgh, Pa.**
Canadian Offices and ..... **Hamilton, Ontario**
Cuban Office ..... **Santiago de Cuba**

Warehouses in Principal Cities

A *miracle* of Annealing Efficiency

Here's the fastest, most accurate annealing system yet developed . . . with a plus feature that *eliminates down time due to repair and maintenance.* Truly a miracle of annealing efficiency. That's the Lee Wilson Single-Stack Portable Base Radiant Tube Annealing System, the latest innovation by the company that invented and developed radiant tube annealing.

A Lee Wilson engineer can prove to you that by using single-stack type furnaces you are able to double production from a given floor area, and with lighter, less expensive auxiliary equipment. The new, doubly efficient, high speed Wilson "O" tube not only steps up production speeds but permits a much greater accuracy of heat control. This means you get faster production of a better product.

And the completely portable base can, when maintenance is required, be detached in a matter of minutes, removed by light crane equipment . . . a spare base dropped in place, and production continued.

There's a lot more . . . for example, expensive basements and understructures have all but been eliminated. But why not get the full story? Write today for a copy of Lee Wilson's Single-Stack Portable Base brochure.

A typical load on a single-stack furnace base . . . 72" in diameter . . . a piling heighth of 156" . . . each coil weighing 20 tons.

The heart of the Lee Wilson Single-Stack Furnace is the "O" Type Radiant Tube arrangement that delivers an input of 500,000 BTU per tube, per hour.

Lee Wilson ENGINEERING COMPANY • INC.

20605 WEST LAKE ROAD • CLEVELAND, OHIO

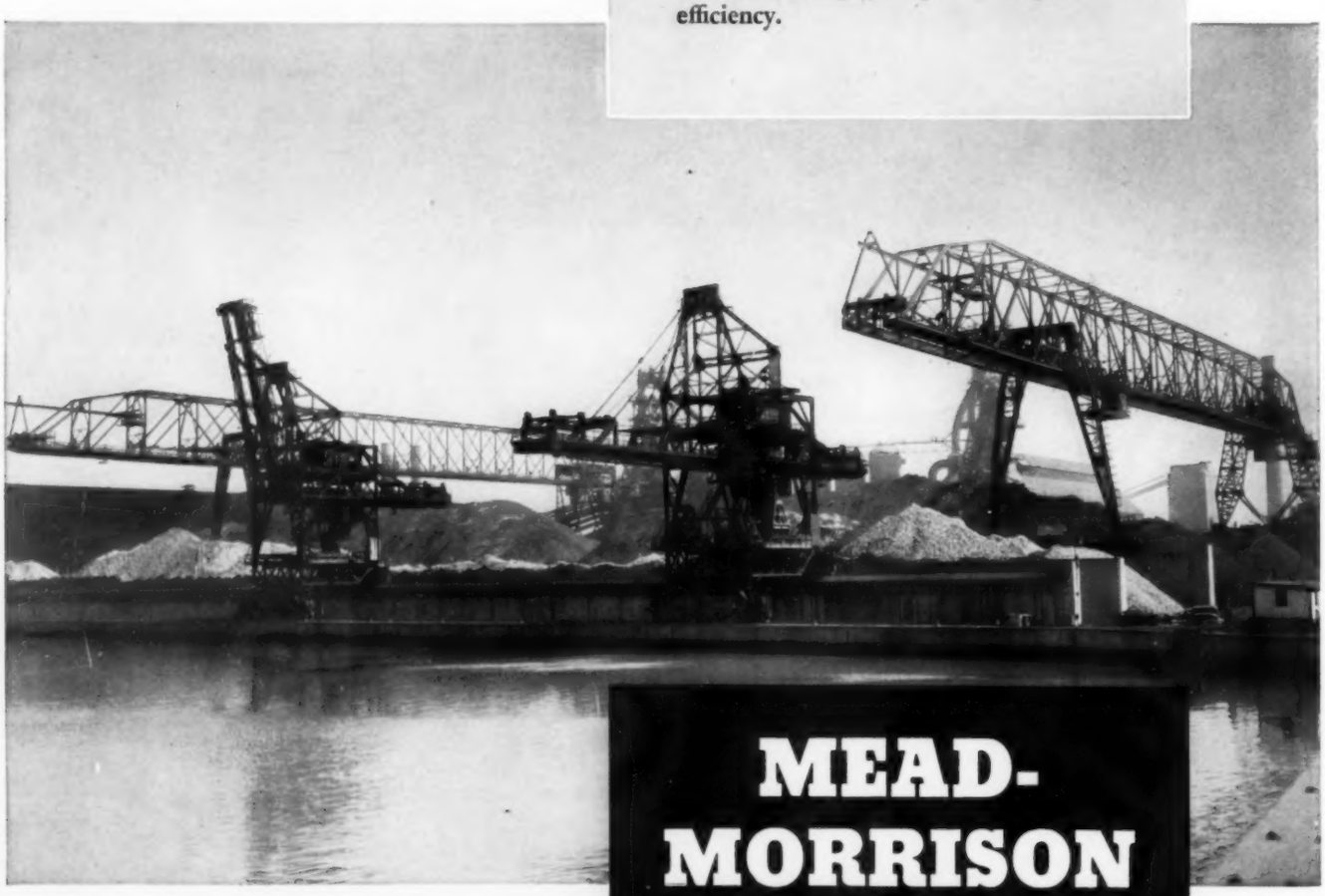
all set for speedy material handling

This team of two Unloaders and two Bridges are part of the Mead-Morrison material-handling equipment at a large midwestern steel mill.

Each of the structures and their equipment has a capacity of 12 tons and is of the man-trolley type. The unloaders discharge ore or limestone from lake steamers, and deposit it in the trough, from which it is rehandled by the bridges to storage piles and to the high line feeding the blast furnaces.

Additional Mead-Morrison Bridges and Unloaders are also operating in the coal storage yard of this same steel company.

If you need new unloading facilities or increased capacity from your present equipment, the Mead-Morrison engineers will help you plan for greatest efficiency.



MEAD-MORRISON

DIVISION OF McKIERNAN-TERRY CORPORATION · MANUFACTURING ENGINEERS · HARRISON, N. J.

MM803

"For over twelve years, the U.S. Rubber Company..."

HARRY E. HUMPHREYS, Jr.
President,
United States Rubber Company

"For over twelve years the United States Rubber Company has offered its employees the Payroll Savings Plan, whereby they can systematically and regularly save in United States Savings Bonds. Over those years, tens of thousands of our employees have joined the Payroll Savings Plan with direct benefits to themselves and their families. Such employees are better employees because with more personal security and freedom from economic worry, there is less absenteeism and personnel turnover, fewer accidents and greater employee responsibility. Such regular investment in Bonds contributes also to the economic strength of the nation. By thus promoting a sounder dollar, business also directly benefits itself. That's why we at United States Rubber endorse the Payroll Savings Plan for Savings Bonds."

Mr. Humphreys cites three important benefits of the Payroll Savings Plan: Payroll Savers build personal security ... production curves reflect serious-minded workers and reduced absenteeism ... the national economy is strengthened by a growing reservoir of future purchasing power—more than 49 billion dollars in U. S. Savings Bonds, *cash value*, held by individuals.

There is still another big advantage in the Payroll Savings Plan: it is easy to install and maintain.

If you do not have the Payroll Savings Plan, or if you have the Plan and your employee participation is less than 60%, here's all you have to do to help your employees, your company and the country:

Write today to Savings Bond Division, U. S. Treasury Department, Washington, D. C. Tell them you want to join the United States Rubber Company and the 45,000 other companies that are making an important contribution to national security and a sounder dollar.

Your State Director, U. S. Savings Bond Division, will contact you promptly. He will explain the simple procedure of installing the Plan and will show you how to conduct a simple, person-to-person canvass that will put a Payroll Savings Application Blank in the hands of every man and woman in your plant and offices.

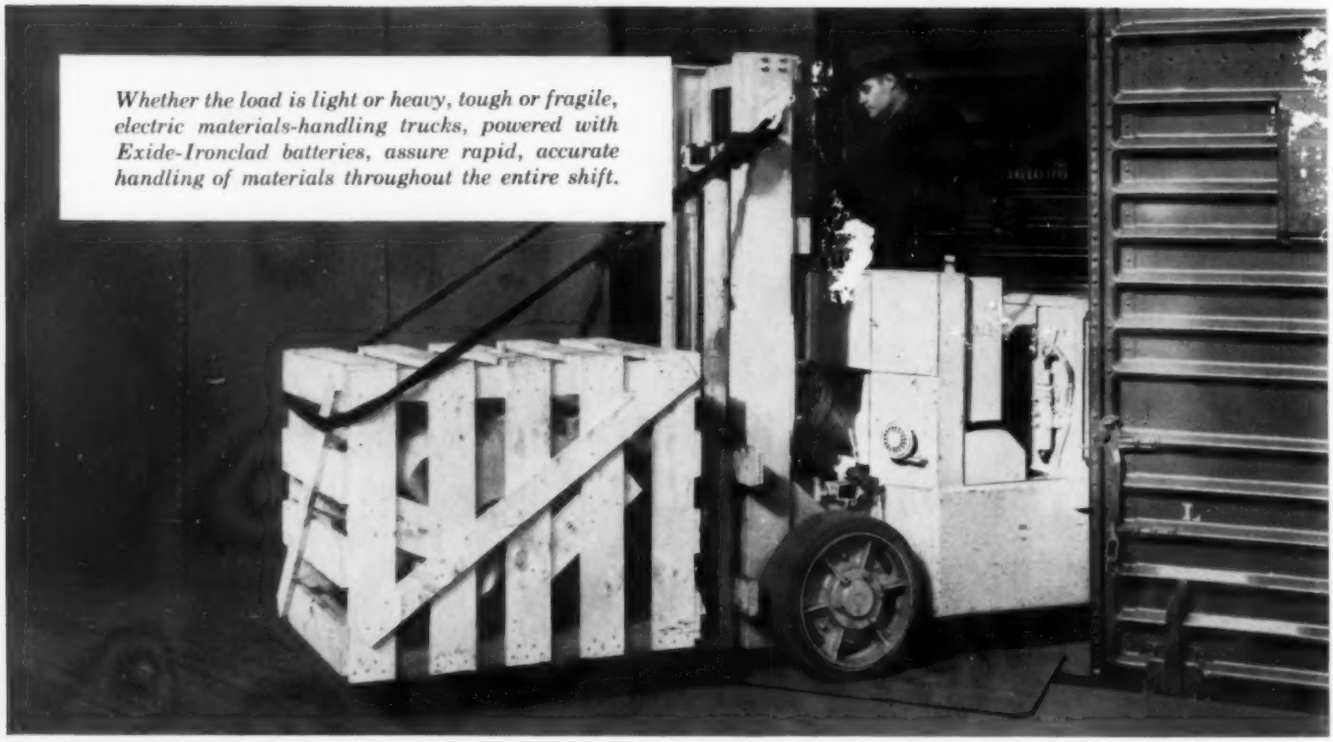
That's all you have to do. Your employees will do the rest. They are as interested in their own future as you are in yours. Give them an opportunity to build personal security for themselves and a better America for their children.

The United States Government does not pay for this advertising. The Treasury Department thanks, for their patriotic donation, the Advertising Council and

IRON AND STEEL ENGINEER

GET FULL SHIFT HANDLING, NO UNSCHEDULED DOWN TIME

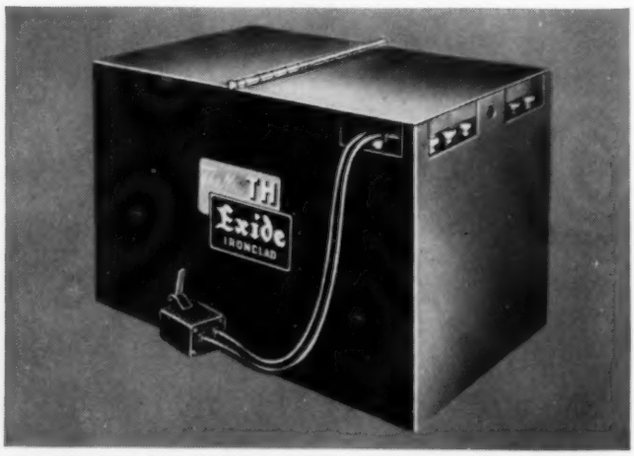
. . . with low cost Exide-Ironclad power!



Whether the load is light or heavy, tough or fragile, electric materials-handling trucks, powered with Exide-Ironclad batteries, assure rapid, accurate handling of materials throughout the entire shift.

YOU GET uniform performance throughout each shift when battery electric trucks are powered by Exide-Ironclads. Your trucks handle as much load during the last hour as during the first . . . with no unscheduled down time. Lower costs for operation, maintenance and depreciation make Exide-Ironclads your best power buy—AT ANY PRICE!

THE POSITIVE PLATES are the heart of any battery. Only Exide uses a slotted tube construction. By use of tubes, more active material is exposed to the electrolyte, providing *greater power.* Also, more active material is retained, giving *longer working life.*



THE NEW THRIFTY HAULER! The improved industrial truck battery. *Non-oxidizing* plastic power tubes assure longest battery life, more capacity in the same space. For full details, call your Exide sales engineer—write for Form 1982 (Installation and Maintenance of Motive Power).

Your best power buy
. . . AT ANY PRICE!

Exide®
IRONCLAD® BATTERIES

Exide INDUSTRIAL DIVISION, The Electric Storage Battery Company, Philadelphia 2, Pa. • *Exide Batteries of Canada, Limited, Toronto*

Publication Service...

MAY, 1954

You Can Obtain...

... any of the bulletins reviewed in the Publication Service of the IRON AND STEEL ENGINEER without obligation or cost. Simply circle the desired item numbers on one of the prepaid postal cards and mail. The requests will be forwarded to the manufacturers involved who will send the bulletins to you.

(1) Insulating Brick

A revised edition of its 12-page insulating brick bulletin is now available from Harbison-Walker Refractories Co. The bulletin now includes data on insulating brick in the following classes: 1600 F, 2000 F, 2300 F, 2600 F, 2800 F and 3000 F. An important feature of the bulletin is a two-page thermal data chart giving heat losses, heat storage capacities, and cold face temperatures for insulated walls built of various combinations of refractories. Data is given for hot face temperatures of 1200 F to 3000 F in steps of 200 F. (Bulletin EB-D).

(2) Motorpump Selection

Recently published by Ingersoll-Rand Co. is a booklet dealing with the selection of the proper motorpump for any specific job. The brochure gives a brief description of what a centrifugal pump is and how it works, pointing out the various factors, such as the quantity, pressure, friction losses and head that must be considered in selecting a pump to meet a specific installation. A typical problem and its solution is presented, together with the material recommended for various pumping installations. (Form 7123).

(3) Industrial Trucks

A new brochure published by Elwell-Parker Electric Co. deals with the application of specially-designed industrial trucks where handling jobs cannot be mechanized in any other way, or where basic truck handling economies can be further increased. These units are often prescribed for the handling of unusual loads; to solve difficult operating conditions; to save investment in new plant facilities; to mechanize costly manual handling jobs; to increase plant safety; to answer floor loading problems; and to reduce maintenance costs of standard trucks operating under severe conditions. The booklet contains more than a dozen actual case histories describing how specially designed trucks solved specific problems. Each example is illustrated, with the text presented in a convenient "problem" and "solution" form. In addition, one section is devoted to drawings and explanatory text covering available attachments for use with fork trucks.

(4) Steel Barges

Prepared to help users select the proper type of waterways floating equipment, a 28-page illustrated booklet just published by Dravo Corp. describes all types of welded steel barges for river and harbor use. A section is devoted to descriptive data and pictures of open and closed hopper barges used by the iron and steel industry to transport large tonnages of raw materials and finished products on inland and coastal waterways. Separate treatment is given tank barges, deck barges, harbor barges and vessels of varied design serving in many special-purpose capacities. More than 50 illustrations are included. Also discussed are design factors, special construction features, barge proportions, size and form, research, and integration. Also included are a series of pictures showing streamlined barge construction methods, and lists available literature and technical data pertaining to waterway transportation, shipbuilding and marine design.

(5) Gas Regulators

Fully described in a new 36-page catalog published by Air Reduction Sales Co. is their complete line of gas regulators. Cylinder, manifold and pipeline regulators are illustrated with complete descriptions covering specifications and operating data. Each regulator has a chart showing types of gages used with it, inlet and outlet connections, maximum flow cfh and maximum working pressure psi. For easy reference, the catalog is cross indexed so that a particular regulator may be located by its uses and by its gas service. Also included are flow and pressure charts indicating at what point the regulators can be used to perform a particular job.

(6) Fire Clay Refractories

A handbook of fire clay refractories has recently been released by Walsh Refractories Corp. Designed to afford helpful information as a handy reference, this volume, 126 pages in length, embraces all of the company's products in addition to providing tables, charts and other valuable data for those using, installing or specifying fire clay refractories. Chapter headings include, research and quality control, fire clay brick, standard and series shapes, high temperature refractory specialties, glass industry refractories, export, palletizing and useful data. Spiral bound, the handbook is sectionalized for greater convenience and contains a unique section finder, affording a quick and easy method of locating wanted information.

(7) Continuous Turbidity Measurements

A revised instrumentation data sheet on continuous indication and recording of turbidity measurements is available from Minneapolis-Honeywell Regulator Co. The new data sheet describes the applications of ElectroniK potentiometers with the new turbidimeter developed and sold by General Electric Co. Of value to any process where suspended solids content of a liquid must be altered, the GE Turbidimeter and ElectroniK potentiometer are an industrial instrument combination designed for precise and long service applications in food, chemical and metallurgical industries, sewage

and water treatment plants, and stream monitoring surveys. (Data Sheet No. 10.14-5).

(8) Unit Heaters

Recently released by Dravo Corp. is a bulletin illustrating a line of commercial and industrial, gas fired, warm air unit heaters having output capacities of 88,000 to 160,000 Btu per hour. The four page folder describes the two types; one for suspended mounting and one that can be built into duct type heating or air conditioning systems. Also included are tables listing heating and air delivery capacities, outlet temperatures, air pressure drops, weights and dimensions of the different units. All models are approved by the American Gas Association for use with natural, mixed or manufactured gases. (Bulletin 543-B).

(9) Water Treatment for Cooling Towers

Water treatment for cooling towers is the subject of a new informational bulletin released by Allis-Chalmers Manufacturing Co. The bulletin discusses types of cooling systems together with such problems as corrosion of metal surfaces, inorganic scaling, organic growths such as algae and bacterial slime, and delignification of the wood in the tower. Information on the selection of chemical treatment is included, along with a table showing the type and amount of treatment found to be effective for prevention of scale or corrosion under various operating conditions. (28X7501A).

(10) Testing Machines

Two low-cost universal testing machines of 20,000 and 60,000 lb capacity are described in a four-page bulletin released by Baldwin-Lima-Hamilton Corp. Principles of their hydraulic straining system and the Tate-Emery null method load indicator are given along with descriptions of accessories and specifications. (Bulletin 4213).

(11) Selenium Charger

A new four-page bulletin published by the Yale & Towne Manufacturing Co., pictures and describes the features of their selenium chargers. Complete dimensions and specifications are included. The chargers were designed for use with motorized electric hand trucks, and are available for either lead or nickel-alkaline type batteries. An important feature of these chargers is that there are no moving parts, thus dependable service is provided without costly maintenance charges. Cooling is by convection — no fan is necessary. The large selenium plate area gives high charging efficiency, and the rugged unit construction ensures long operating life. (Bulletin P-1333).

(12) Storage Battery Maintenance

A new eight-page pocket-sized booklet on storage battery maintenance has been published by Exide Industrial Division of the Electric Storage Battery Co. The booklet breaks down battery care to seven basic rules, each emphasized with a catchy cartoon treatment and a minimum of explanatory text. The booklet is particularly suitable for distribution to maintenance personnel and others who might have to deal with batteries. It should prove both useful and interesting to anyone associated even indirectly with batteries, such as purchasing department personnel, industrial truck and mine locomotive operators, locomotive engineers and railway car maintenance workers, operators of marine craft, municipal maintenance personnel and members of industrial plant engineering departments. (Form 5063).

(13) Recommendations on Open Hearth Construction

Detailed charts and cross-sectional drawings showing proved recommendations for high temperature insulation in open hearth furnaces are available in booklet form from Illinois Clay Products Co. Charted are the open hearth furnace checker chamber, fan tail arrangement and a sectional view of insulation required above the charging floor. Thermal comparisons are tabulated showing Btu savings for insulated refractories as compared with non-insulated refractories.

(14) Automatic Etching Process for Steel Mill Rolls

A new bulletin devoted to the subject of how to automatically and mechanically etch steel mill rolls has been published by American Wheelabrator & Equipment Corp. The bulletin explains how major steel companies are using the airless abrasive blasting process in specially-designed automatic cabinets to achieve benefits, including: (1) they etch more rolls in less time, (2) achieve a more uniform etch than with manual methods commonly used, (3) obtain greater roll life per etching, (4) eliminate human failures, (5) control degree of etch more accurately. Engineering diagrams are included in the bulletin to show the mechanics of presenting the roll to the abrasive blast. Several illustrated case histories are included. (Bulletin 984).

(15) Metals Chart

An extremely useful calculating wheel created as an aid to designers, engineers or anyone requiring a quick source of all the physical properties of the various types of Meehanite metals available to industry, is found in a chart made available from the Meehanite Metal Corp. The chart provides the engineering characteristics of all metals in the four major classifications under which Meehanite castings are produced — namely, general engineering, heat-resisting, corrosion-resisting and wear-resisting.

(16) Turbine Speed Control

Elliott Co. has published a new 30-page bulletin on turbine speed control. It is an elaborately illustrated, educational bulletin intended to clarify the operation of common types of automatic speed control for steam turbines. An introductory section covers general fundamentals of automatic control systems, and includes a key to control terminology, giving equivalent terminology used in connection with instrument and regulator applications. Simplified diagrams in three colors illustrate operating principles of actual control systems. (Bulletin H-21).

(17) Centrifugal Pump

A four-page illustrated bulletin containing design features and specification data on their type GS (General Service) pump has been issued by the De Laval Steam Turbine Co. The new bulletin illustrates the ease of maintenance and service features of the pumps, including the rotor assembly which contains all working parts and which lifts out of the casing as a single unit. Other features are the mechanical seal and life-time lubricated bearings. (Bulletin 1001B).

(18) Safety Booklet

A new 32-page booklet now being offered by Air Reduction Sales Co. is specifically designed for welding and cutting operators handling oxyacetylene and arc welding equipment. Based on the principle that "safety is no accident," the booklet details safety cautions and rules for personal safety, the handling and maintenance of cylinders, torches, regulators and hoses. It discusses safe practices in setting up, adjusting, using and shutting down of the equipment. The story is presented in a clear, concise way with sketches illustrating safe practices as well as some of the mal-practices in the welding and cutting field.

(19) High Voltage Switchgear

A 24-page guide to high voltage switchgear is available from I-T-E Circuit Breaker Co. Illustrated with diagrams and photographs, the bulletin contains separate sections on features, switchgear components, applications, specifications, and construction data. Detailed information is tied in with easy-to-see photographs and diagrams. It also deals with extra services which are available to users of switchgear. (Bulletin 7004B).

(20) Motor Selection

Designed to help in quickly choosing Reliance squirrel cage induction motors, both the new line and the current line, for applications ranging from one to 200 hp, a colorful, 12-page bulletin has just been issued by the Reliance Electric and Engineering Co. The new bulletin lists performance characteristics, construction features, dimensions, price, and other information essential in ordering the "right motor for the job." (Bulletin B-2102).

(21) Tempering Furnaces

A new 20-page catalog published by Leeds & Northrup Co., tells operating results being obtained in hundreds of plants by users of "Homo" furnaces. Photos and descriptions of typical installations, cut-away views of the furnaces, description of the control instruments, and complete specifications about furnace sizes, work baskets and trays are given. (Catalog TD2-625).

(22) Electric Motor Control

Data on industrial electric motor control by the Rowan Controller Co. is now available in an illustrated 20-page booklet showing their line. The descriptions of their products include float, drum, lighting, and disconnect switches plus motor and voltage starters, motor controls, and a centralized control system.

(23) Traveling Cranes

A 30-page bulletin on Browning electric, overhead, traveling cranes has been published by Victor R. Browning & Co., Inc. These cranes feature modern, welded construction and are designed for mill and industrial applications to AISE specifications. This bulletin illustrates their various cranes along with component parts, types, features, and functions. A clearance table is also provided.

(24) Current-Limiting Fuses

A new booklet on current-limiting fuses has just been announced by General Electric Co. Information given in the publication includes: where and why these fuses should be used; construction details of the fuses; ratings; dimensions; curves showing current-limiting characteristics and melting time-current characteristics for both 250-volt and 600-volt fuses. (16-74).

(25) Super-Duty Fireclay Brick

Two super-duty fireclay brick are detailed in a new eight-page bulletin published by Harbison Walker Refractories Co. These brick offer high refractoriness, high resistance to spalling, high resistance to fluxes, low porosity, stability of volume and strength at high temperatures. The brochure includes technical details, application information and a variety of charts which indicate such properties as refractoriness, porosity, linear subsidence, alumina content and the relative loss in the panel spalling test.

(26) Electric Fork Truck

A new 16-page illustrated brochure offered by the Clark Equipment Co., presents a thorough exploration of its electric fork truck line. Construction features of the machine are interpreted through the use of schematic drawings. A cut-away view of the double-acting tilt cylinders explains their operation. The three separate brakes which are standard equipment on these electric trucks are also described and illustrated. Vital parts making up the integral drive unit are pictured with an explanation of the operation of the drive unit in response to the control circuit.

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BUSINESS REPLY CARD
First Class Permit No. 1963, Sec. 34.9, P. L. & R. Pittsburgh, Pa.

IRON & STEEL ENGINEER
1011 EMPIRE BUILDING
PITTSBURGH 22, PA.

IRON & STEEL ENGINEER
Send The *free* Booklets Circled Below:

MAY, 1954

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PUBLICATIONS CURRENTLY OFFERED by Iron and Steel Engineer Advertisers

ITEM	COMPANY	BULLETIN	DESCRIPTION
50	ADALET MFG. CO.	BULLETIN G-452a	Information on cable supports and seals.
51	AEROVENT FAN CO.	FOLDER P-50	Details on new portable utility fans.
52	ALLIS-CHALMERS MFG. CO.	BULLETIN 11B6285B	24-pages describing switchgears for power distribution.
53	AMERICAN WHEELABRATOR & EQUIPMENT CORP.	BULLETINS 894 & 914	Details on descaling strip and sheet mechanically.
54	BEDFORD FOUNDRY & MACHINE CO., INC.		Complete catalog describing Bedford cranes.
55	E. W. BLISS CO.	CATALOG 40-A	60-page revised rolling mill brochure.
56	BRISTOL CO.	BULLETIN G621	Information on gages for recording, controlling and telemetering.
57	BRISTOL CO.	BULLETIN P1261	Complete story on new metal-ceramic protecting tubes.
58	BROOKS OIL CO.		Descriptive booklet on lead-base lubricants.
59	BUSSMANN MFG. CO.	BULLETINS FIS & HCS	Blowing time charts and fuse information.
60	CLARK EQUIPMENT CO.		Booklet describing features of electric fork trucks.
61	DURABLA MFG. CO.		Bulletin on pump valve units.
62	ELECTRIC CONTROLLER & MFG. CO.	BULLETIN 18	Complete facts on WB type brakes.
63	ELECTRIC CONTROLLER & MFG. CO.	BULLETIN 900	24 page bulletin shows lifting magnets at work.
64	ELECTRIC STORAGE BATTERY CO.	FORM 1982	Details on installation and maintenance of motive power.
65	FARVAL CORP.	BULLETIN 26	Complete story on centralized systems of lubrication.
66	GENERAL ELECTRIC CO.	BULLETIN GEA-4654	Facts on G-E armored motor with low armature inertia.
67	GENERAL MOTORS CORP., HYATT BEARINGS DIV.	CATALOG 150	General catalog on roller bearings.
68	IDEAL INDUSTRIES, INC.		39-page handbook on commutator maintenance.
69	INDUSTRIAL GEAR MFG. CO.	BULLETIN 152-A	Pictorial visit through gear and sprocket cutting plant.
70	W. A. JONES FOUNDRY & MACHINE CO.	CATALOG 100	Speed reducer Catalog.
71	KOPPERS CO., INC., FAST'S COUPLING DEPT.		Fast's coupling catalog.
72	LINK-BELT CO.	BOOK 2416	48-page catalog on belt conveyor idlers.
73	LINTERN CORP.	BULLETINS AC-544 & AC-533	Description of and recommendations for Aire-Rectifiers.
74	MINNEAPOLIS-HONEYWELL REGULATOR CO.	CATALOG 1531 & DATA SHEET 6.4-11	Details on control with electronic instruments.
75	NORTHERN ENGINEERING WORKS	BULLETIN HL-115	Facts on Hi-Lift cranes.
76	OHIO ELECTRIC MFG. CO.	BULLETIN 12	Information on magnet performance.
77	PACIFIC PUMPS, INC.	BULLETINS 106, 109, 118	Details on pumps in feed water service.
78	Pittsburgh Lectromelt Furnace Corp.	BULLETIN 9	Description of electric furnaces.
79	PLASTEEL PRODUCTS CORP.		Engineer's handbook on use of Plasteel roofing and siding.
80	PYLE-NATIONAL CO.	CATALOG 1100 & BULLETIN 1140-2	Complete listings of plugs and receptacles.
81	REFRACTORY & INSULATION CORP.		Story of Moldit castable refractory.
82	ROWAN CONTROLLER CO.		Booklet describes oil immersed motor starting equipment.
83	RUST-OLEUM CORP.		Complete literature about Rust-Oleum.
84	SIMMONS MACHINE TOOL CORP.		Details on machine tool rebuilding.
85	SPRAYING SYSTEMS CO.	DATA SHEETS 3997 & 4516	Information on descaling nozzles and direct spray gear lubrication nozzles.
86	S. G. TAYLOR CHAIN CO.	BOOKLET 12C	Facts and specifications on alloy steel chain.
87	UNITED STATES GRAPHITE CO.		Complete brush catalog.
88	WAGNER ELECTRIC CORP.	BULLETIN MU-185	Full information on complete line of motors.
89	WALKER PROCESS EQUIPMENT, INC.	BULLETIN 10I69	Literature on blast furnace flue dust recovery plant.
90	LEE WILSON ENGINEERING CO., INC.		Single-stack portable base furnace brochure.

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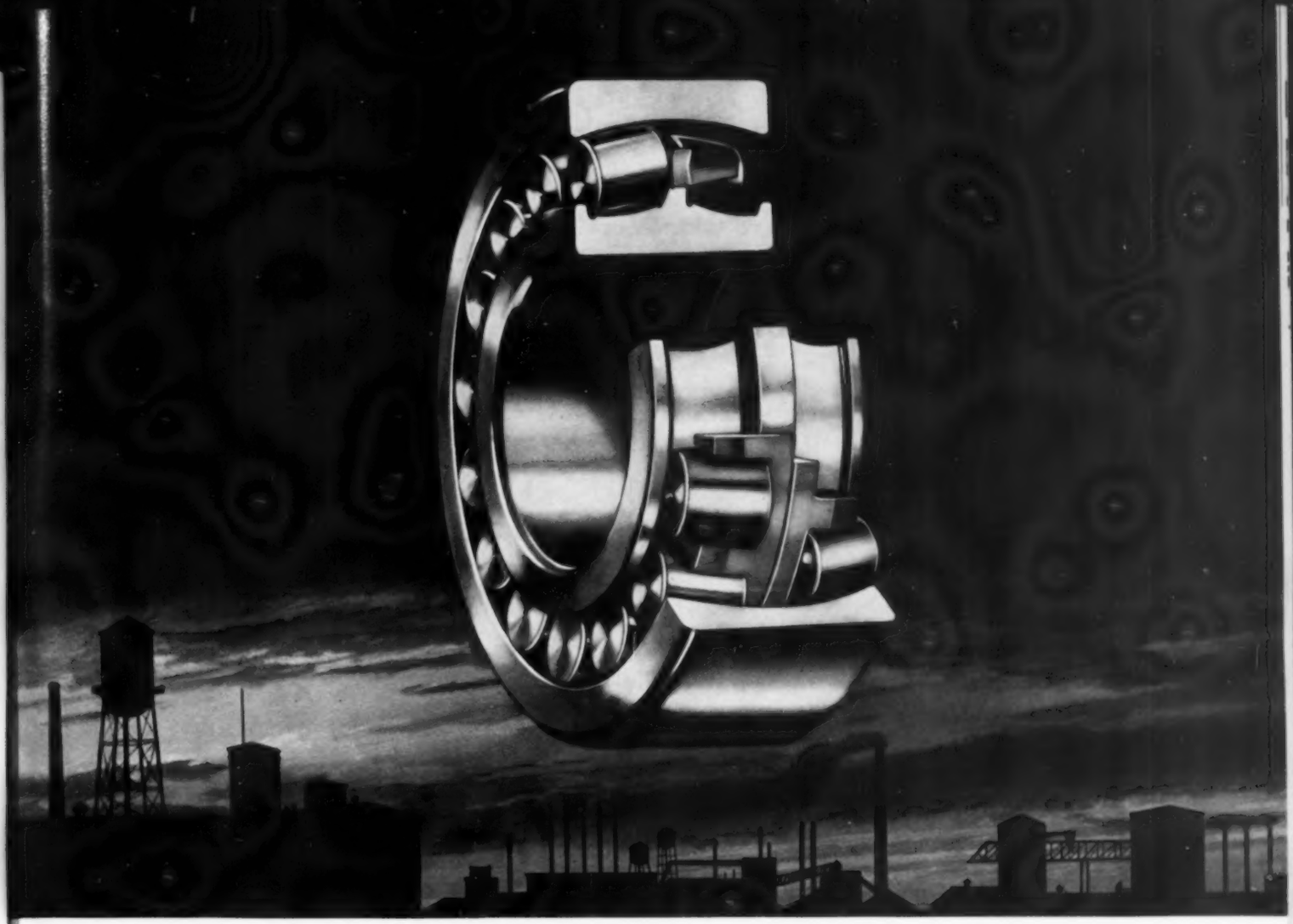
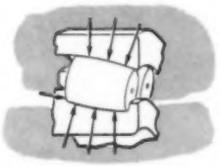
1011 EMPIRE BUILDING

PITTSBURGH 22, PA.



Why it pays to specify
TORRINGTON Spherical Roller Bearings

Uniform, close control of precision-ground contact surfaces—for even load distribution, maximum bearing life.



Accurate geometrical conformity between races and rollers—for ultimate capacity and performance.

Races and rollers heat treated according to the most advanced metallurgical procedures.

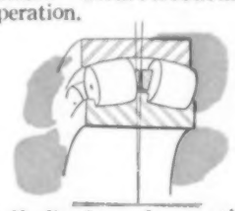
Machined, cast-bronze cages—one for each path of rollers—assure freedom of operation.

Integral center flange on inner race—to give positive radial and thrust stability—both essential to satisfactory performance.

Available from stock with either straight or tapered bore—for shaft or adapter mounting.

These are advantages that give you long, efficient, low-maintenance service in the toughest heavy-duty applications... **maximum value for your bearing dollar.** ***That's why it pays to specify TORRINGTON Spherical Roller Bearings.***

THE TORRINGTON COMPANY
South Bend 21, Ind. • Torrington, Conn.



Self-aligning—for continuous, free-rolling service under shock loads and at sustained speeds.

Unit assembly—for easy, low cost handling.

TORRINGTON SPHERICAL ROLLER **BEARINGS**

Spherical Roller • Tapered Roller • Cylindrical Roller • Needle • Ball • Needle Rollers

Put in to Stay in Longer

MOLDIT CASTABLE REFRACTORY

in Annealing Furnace Bases

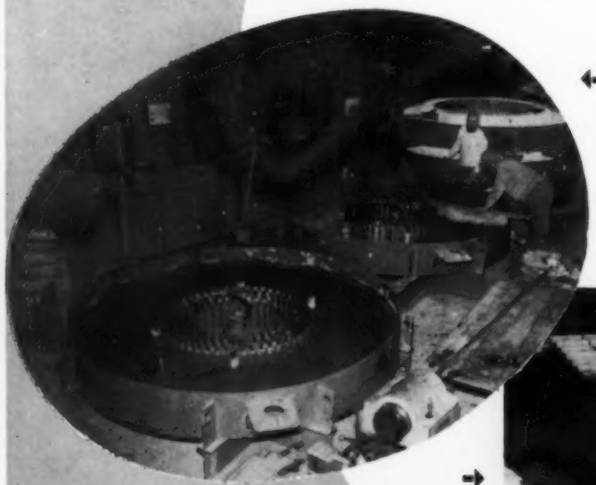
Bases for annealing furnaces made of Moldit D Refractory Cement, with surrounding sand seal area of Light Weight Moldit #80 insulating refractory. This installation cut repairs in half. Not a crack appeared in setting or drying. Has given double the life of other refractory materials.

▶ **INSTALLED IN HALF THE TIME**

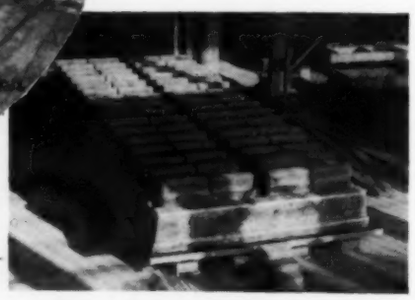
▶ **OUTLASTS OTHER REFRACTORIES**

Moldit—the pioneer line of castable refractory materials—has been cutting maintenance costs as much as 90% in reheating and annealing furnaces because of its quick installation and long service life.

Easy to pour, trowel or even "gun" into place, in any monolithic section of any shape and size, Moldit air-sets to full refractory hardness and is ready for use in a few hours. There is the right type of Moldit with the right workability and durability for every furnace application. Write for the Moldit story today.



← Circular bases of bell type annealing furnaces being made of Light Weight Moldit #55 insulating refractory, a strong, very economical material for this type of furnace base.



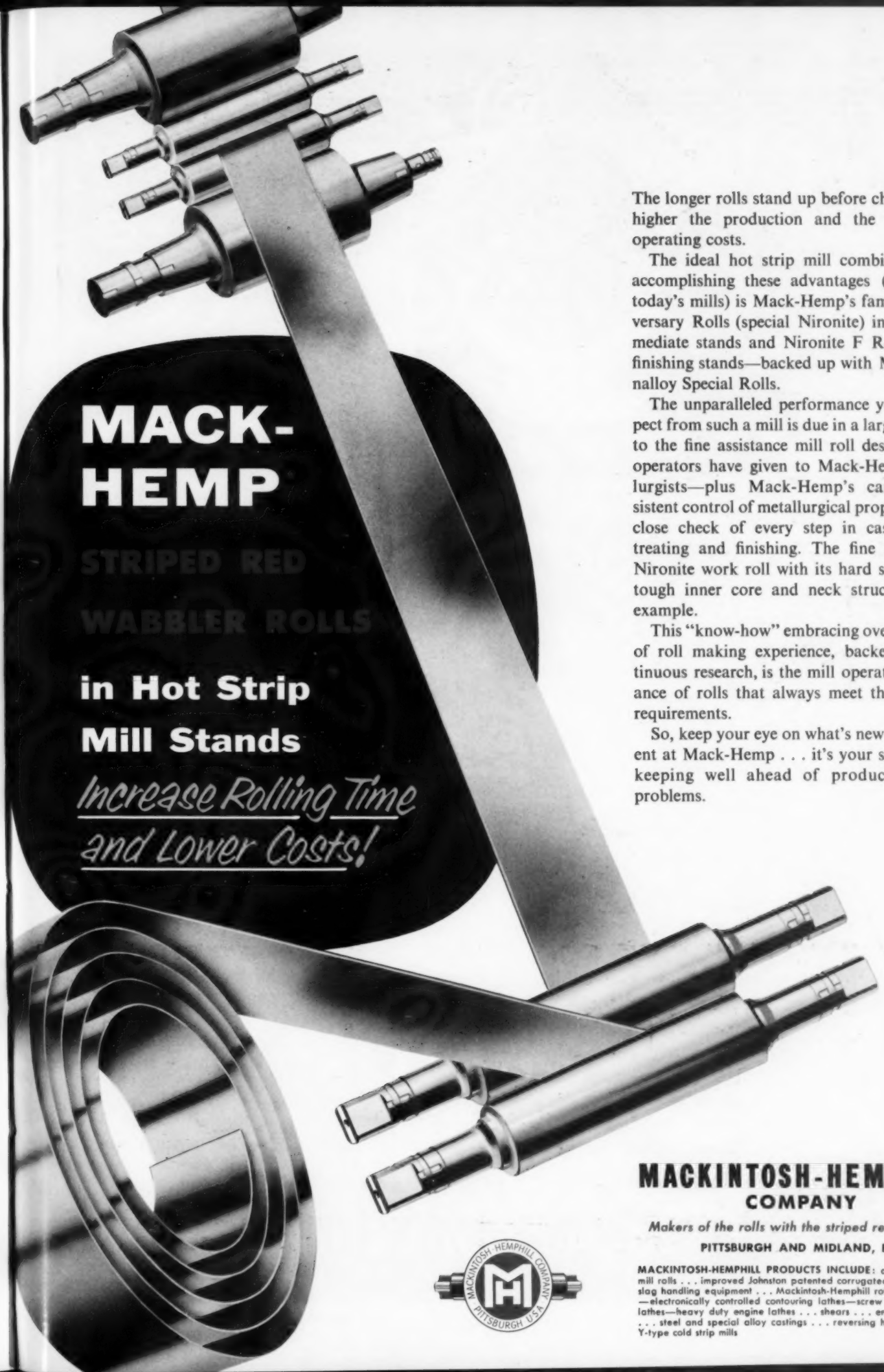
→ Car bottom and piers for steel annealing furnace cast from Moldit Pier Cement.

REFRACTORY & INSULATION CORPORATION

R&I

Refractory Bonding and Castable Cements — Insulating Block, Blankets, Cements

136 WALL STREET • NEW YORK 5, N. Y.



The longer rolls stand up before changes, the higher the production and the lower the operating costs.

The ideal hot strip mill combination for accomplishing these advantages (proved in today's mills) is Mack-Hemp's famous Anniversary Rolls (special Nironite) in the intermediate stands and Nironite F Rolls in the finishing stands—backed up with M-H Technalloy Special Rolls.

The unparalleled performance you can expect from such a mill is due in a large measure to the fine assistance mill roll designers and operators have given to Mack-Hemp metallurgists—plus Mack-Hemp's careful consistent control of metallurgical properties, and close check of every step in casting, heat treating and finishing. The fine grain type Nironite work roll with its hard surface and tough inner core and neck structure is an example.

This "know-how" embracing over 150 years of roll making experience, backed by continuous research, is the mill operator's assurance of rolls that always meet their specific requirements.

So, keep your eye on what's new and different at Mack-Hemp . . . it's your sure way of keeping well ahead of productioneering problems.

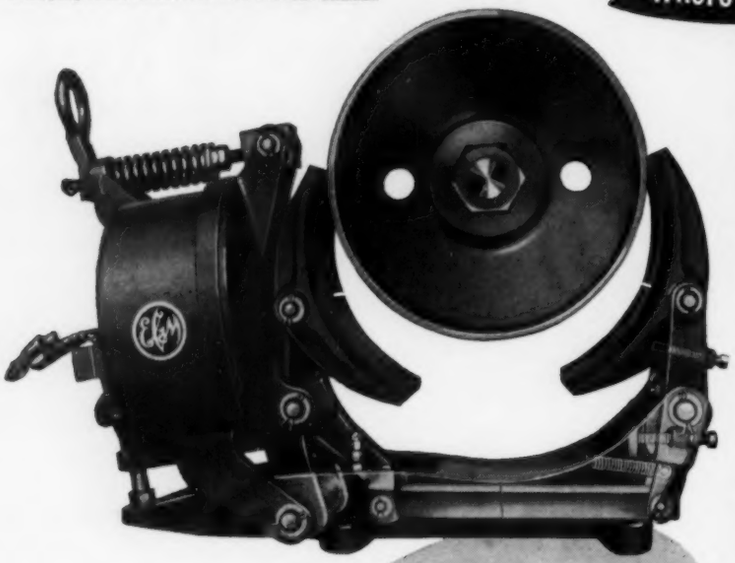
MACKINTOSH-HEMPHILL COMPANY

Makers of the rolls with the striped red wabblers

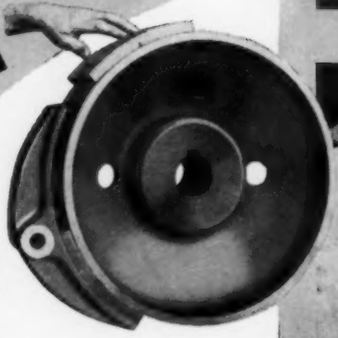
PITTSBURGH AND MIDLAND, PA.

MACKINTOSH-HEMPHILL PRODUCTS INCLUDE: all types of cast mill rolls . . . improved Johnston patented corrugated cinder pots and slag handling equipment . . . Mackintosh-Hemphill rotary straighteners —electronically controlled contouring lathes—screw feed roll turning lathes—heavy duty engine lathes . . . shears . . . end-thrust bearings . . . steel and special alloy castings . . . reversing hot strip mills . . . Y-type cold strip mills

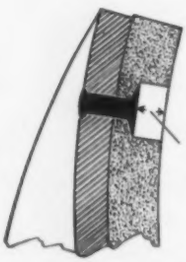
Type WB Brake showing how the motor armature is easily lifted out. At top left is the handle-nut for compressing the spring when removing motor armature, changing brake shoes and for manual control.



Long Life Brakes for A-C and D-C Motors by EC&M



The brake lining is molded to match curvature of wheel and shoe.

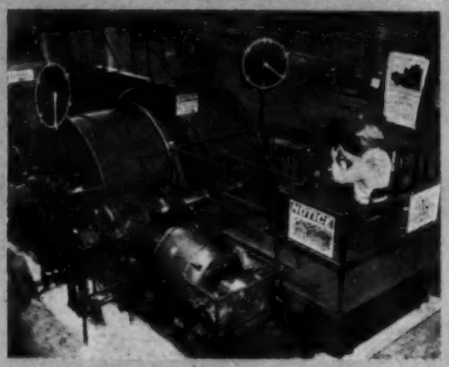


Actual wearing thickness, between rivet heads and brake wheel, is 1/8" on the smallest size to 3/16" on the largest size.

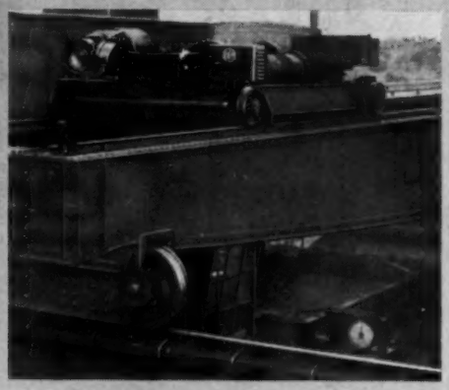
These Type WB Brakes use a block type lining which is both thick and tough.

Furthermore, due to the process of manufacture, the blocks have proper frictional quality *throughout the entire thickness* permitting uniform and complete wear down to rivet heads. And since the material is non-compressionable, brake adjustments are infrequent.

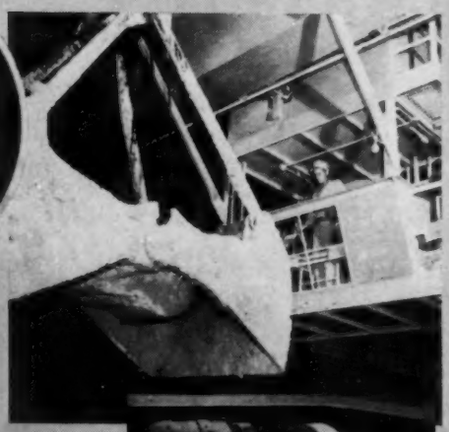
Where You Will SAVE With WB Brakes



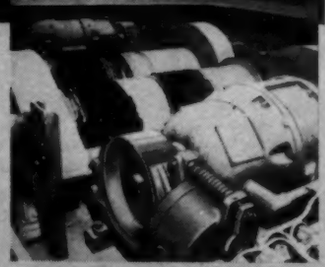
A-C Mine-Hoist Motor with WB Brake



Reduces Delays on Foundry Crane



Bucket-Crane Trolley with WB Brake



WRITE FOR COMPLETE FACTS—Ask for No. 18 ACCELERATOR Bulletin

THE ELECTRIC CONTROLLER & MFG. CO.

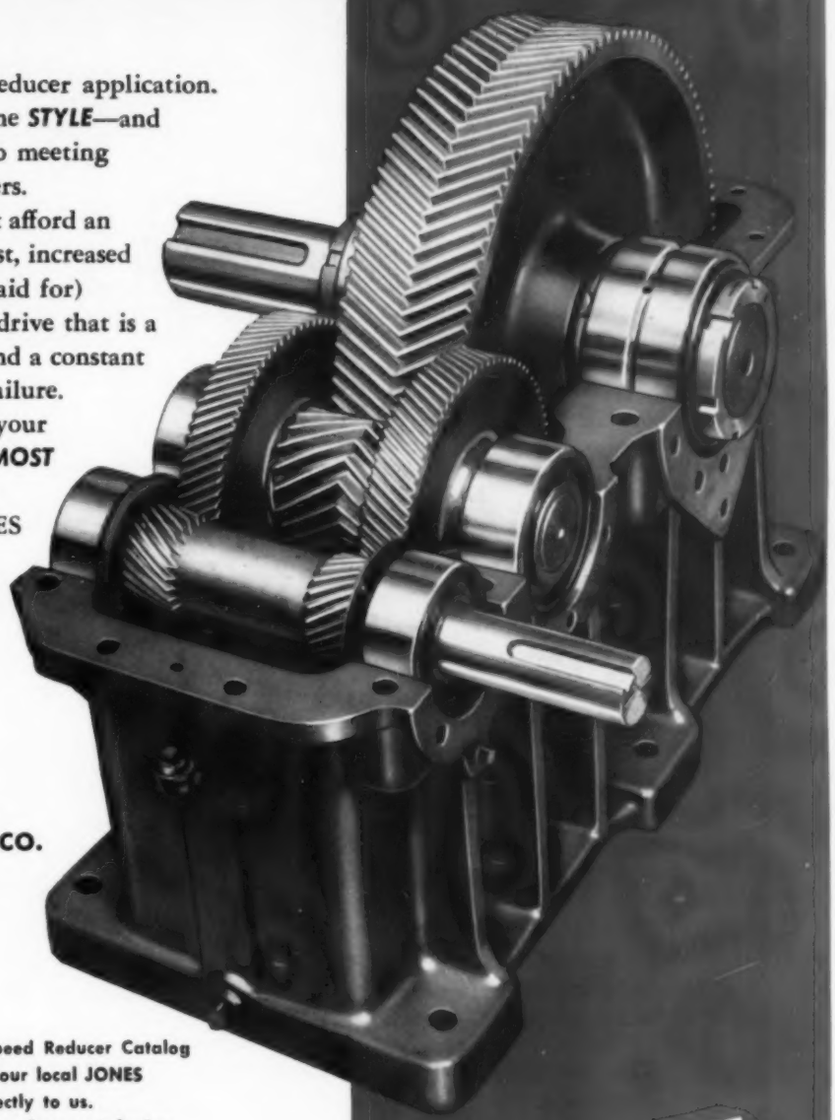
2698 EAST 79TH STREET • CLEVELAND 4, OHIO

Why pay for USELESS HORSEPOWER?

For every Herringbone Gear Speed Reducer application. there is always one ***SIZE***—one ***TYPE***—one ***STYLE***—and one ***ASSEMBLY*** that will come closer to meeting the required specifications than all others.

With today's high costs you just can't afford an oversize drive with its higher initial cost, increased installation expense and useless (but paid for) horsepower capacity—or an undersize drive that is a hazard to more expensive equipment and a constant threat to production schedules due to failure.

Select the drive that ***REALLY FITS*** your requirements from the ***NEWEST AND MOST COMPLETE LINE*** of Herringbone Gear Drives available anywhere — the JONES line. Choose from a ***WIDER*** range of standard drives which includes ***MORE*** in-between sizes—***MORE*** standard ratios for every size—plus ***MORE*** standard larger size units to meet the growing demands of heavier load conditions.



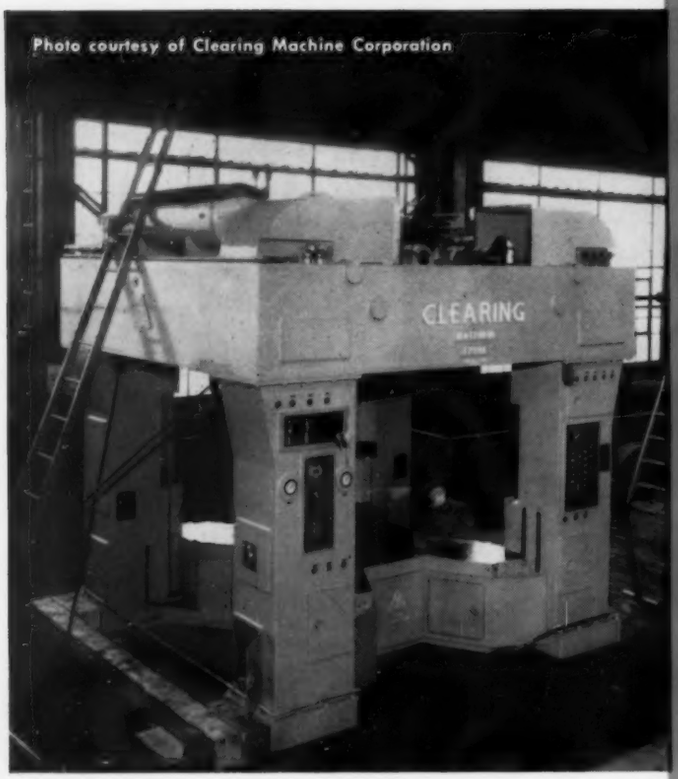
W. A. JONES FOUNDRY & MACHINE CO.
4431 Roosevelt Road, Chicago 24, Illinois

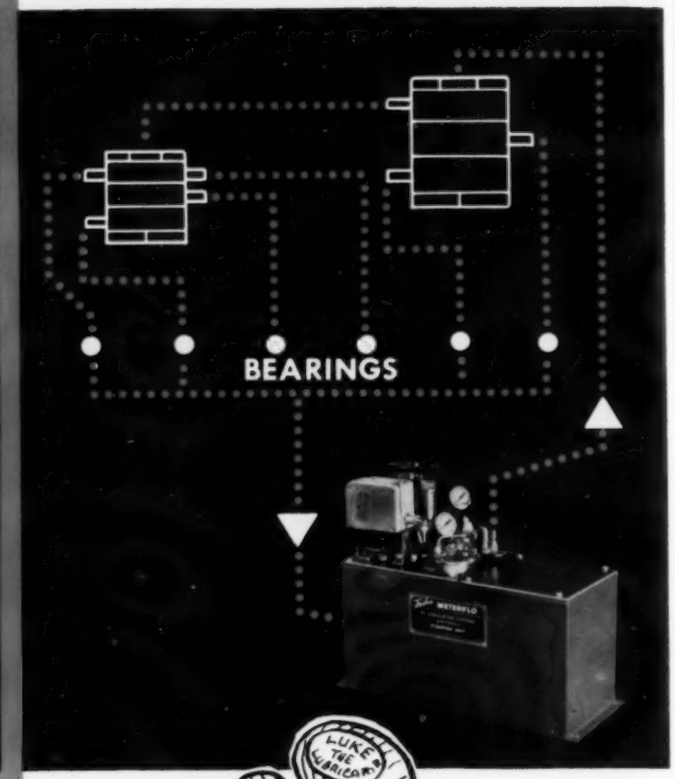
Our ***NEW*** Herringbone Speed Reducer Catalog No. 100 is available from your local JONES Representative, or write directly to us. This new approach to speed reducer cataloging is specially designed to help you select with accuracy and confidence the correct Herringbone Gear Drive for your specific application.

Better Drives ...Since 1890

Jones

HERRINGBONE—WORM—WORM HELICAL—GEAR SPEED REDUCERS
CAST IRON PULLEYS • CUT GEARS • V-BELT SHEAVES
ANTI-FRICTION PILLOW BLOCKS • FLEXIBLE COUPLINGS





Trabon's METERFLO OIL CIRCULATING SYSTEM *ELIMINATES TROUBLE*

ON 20-TON WELDING PRESS

This is one of an installation of 36 four-point welding presses in a large automotive plant, all automatically lubricated by TRABON METERFLO systems.

TRABON *positive* lubrication assures all of the 68 bearing points on each press the right amount of filtered oil at the right time. Remote indicating gauges are mounted in the left-hand corner column of the presses for easy visibility. Warning lights flash on in the event of interrupted flow of oil to the bearings.

This installation is typical of the thousands of TRABON automatic lubrication systems in operation in industry everywhere . . . under all manner of operating conditions, indoors or outdoors, underground or on the surface.

Trabon ENGINEERING CORPORATION
1814 E. 40th STREET • CLEVELAND 3, OHIO
Oil and Grease Systems

Equipment News...

SLITTING UNIT

▲A new machine for slitting and edge rolling with as little trim or waste as the thickness, or less than the thickness of the steel, has been designed and built by the J. L. Golding Manufacturing Co., and is now being used by Economy Steel Service Co.

With the new machine, Economy Steel has been able to produce work hitherto impossible.

As an example, a quantity of coil steel was slit by one of the warehouses to $1\frac{5}{16}$ in. wide, but due to an error it was .0065 in. to .008 in. wider than normal slitting tolerance. This material was rejected by the customer because the additional width would not work satisfactorily for the customer's application. Economy Steel reworked these coils and slit only .008 in. from them, reducing the coils to the exact width required.

This enabled the original seller to salvage what would have been a rejected order and the material would have found its way to the scrap pile.

Another illustration concerns a manufacturer who found himself with a large quantity of slit coil steel obsoleted because of a change in model or design. Economy Steel slit the coils into two strips, both of which were the required width, even though there was no trim allowed in order to accomplish this. This slitting was held to a ± .003 in. with no resulting camber.

Edge rolling of light gauge metals has always presented a major problem. Economy Steel's new equipment handles this operation as a routine job.

The customary or average waste resulting from slitting is between $\frac{3}{8}$ in. and $\frac{1}{2}$ in. Elimination of this waste can become a substantial saving, through the use of Economy's new equipment, particularly when such metals as stainless steel, aluminum, brass, bronze or other higher cost metals are used.

Slitting of narrow coils with a drop-off or scrap equal to the thickness of the metal often more than equals the cost of slitting.

Tonnage, which because of die or model changes have become obsolete, have thus become current and usable.

This slitter and edge roller in use at Economy Steel Service Co. reduces trimming waste to the thickness of the steel, or less. Gage of steel coil ready for slitting is being checked here.

INSTRUMENTS

▲A new line of process instruments including potentiometric and a-c bridge recorders and recording controllers has been announced by the General Electric Co.

The instruments, designed for continuous measurement and control uninterrupted by periodic standardization, incorporate new measurement circuitry and components, according to company engineers. Foremost among the new features are a magnetic standard in the potentiometric system and a bridge-balancing unit in the a-c bridge system.

Both models are available with either electric or pneumatic control, and are equipped with a unique centerless pointer that simplifies chart changing and leaves practically all of the chart exposed to view for easy reading.

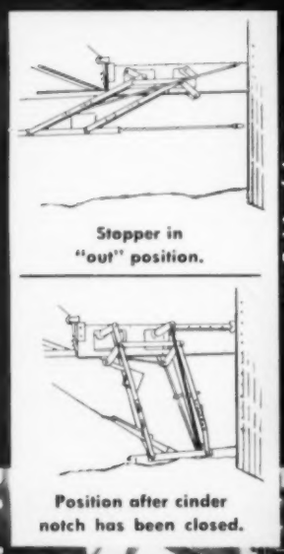
According to G-E engineers the new magnetic standard eliminates dry cells, slidewires, and many moving parts found in conventional potentiometric instruments.

Heart of the a-c bridge system, the new bridge-balancing unit supplies power to the bridge and provides a means for rebalancing it. In cases where the variable under measurement is temperature, the circuit is

Bailey

Cinder Notch Stopper

keeps workmen out of a danger zone



Stopper in "out" position.

Position after cinder notch has been closed.

Since the Bailey Stopper is controlled remotely, no workman need approach the cinder notch—assuring safe, dependable closing every time. Gravity action inserts the bott in the monkey, and an air or steam powered cylinder withdraws the stopper to the "out" position. Design is such that alignment is true at all times. For durability, both the bott and rod are water-cooled.

WILLIAM M. Bailey COMPANY

ENGINEERS

LEADERSHIP THROUGH QUALITY

1221 BANKSVILLE ROAD PITTSBURGH 16, PA

unbalanced by changes in the resistance bulb. Balancing is achieved by a servo motor which repositions the balancing unit's rotor.

Other advantages of the equipment include plug-in components, anti-backlash gearing, internal illumination, and an integral pen-inkwell assembly designed for automatic realignment.

The reinforced steel case and die-cast aluminum cover are sealed with Neoprene gasketing against dirt and moisture, and can be furnished for either wall or flush mounting.

CONVEYOR

▲An all-aluminum conveyor, now available from Farnco Sales Co., should prove valuable in moving materials through small openings and narrow passageways.

Built entirely of extruded aluminum, the conveyor is braced lengthwise and crosswise. The wheel assembly can be removed for tight clearances.

The conveyor features cleanout and scraper at both tail and head ends, shock plates along its full length and sealed-in anti-friction bearings throughout.

Powered by an electric, gas, or air motor, the unit can be used in cleaning checker chambers, carrying slag from heating furnaces, cleaning scale-pits in rolling mills and under runout tables, rebuilding brick, and for general hauling.

SPLICER

▲E. W. Bliss Co. recently announced that it has acquired the manufacturing rights of the "Weld-a-Matic" Splicer from the dissolved Arms-Franklin Corp. The agreement transfers to Bliss patent rights, engineering drawings, service, operating and empirical data.

The splicer has many uses in the metal industries, including the splicing of ferrous and non-ferrous strip, required for coil build-up, continuous feeding of skelp in light-walled pipe manufacture, reuniting silicon sheets into continuous strands and coils, following special processing, etc.

The principle involved permits the butt-welding by shielded arc method of low, medium and high-carbon steel strip, stainless strip in both the

● The cost of Ajax Dihedral Couplings is insignificant compared to the cost of downtime in any department of any mill! America's foremost designers of heavy mill equipment are welcoming the ability of Ajax Dihedral Couplings to handle heavy horsepower, high speeds, and shock loads under rolling mill conditions.

Long life and trouble-free operation without the usual maintenance on spindle drives between pinion stands and rolls.

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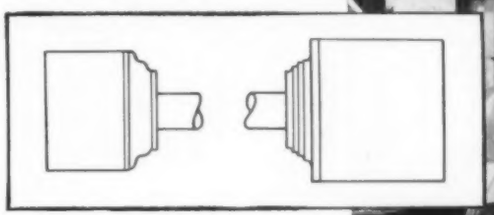
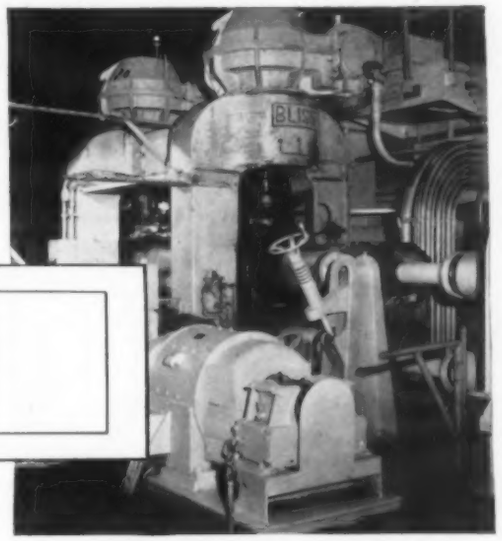
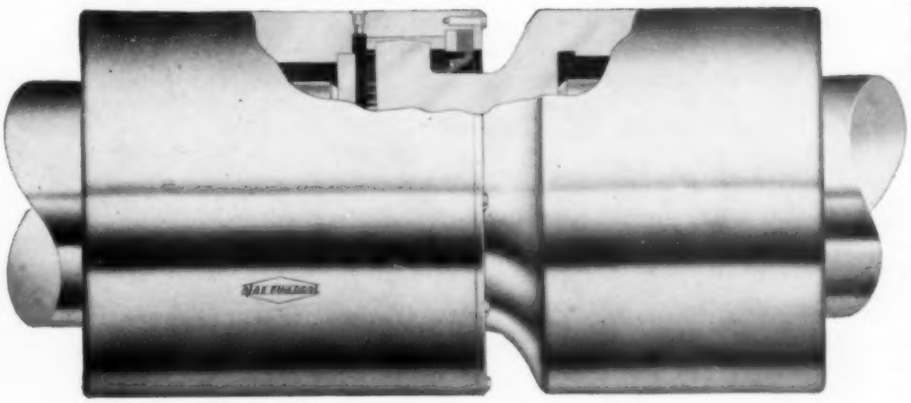


Cut-away view of Ajax Spindle Shaft Dihedral Coupling as used between pinion stands and rolls.



Showing two sets of Ajax Spindle Shaft Dihedral Couplings installed on Bliss 32" x 80" Two-High Temper Pass Mill in operation at the Fairless Plant of the U. S. Steel Corp., Morrisville, Pa.



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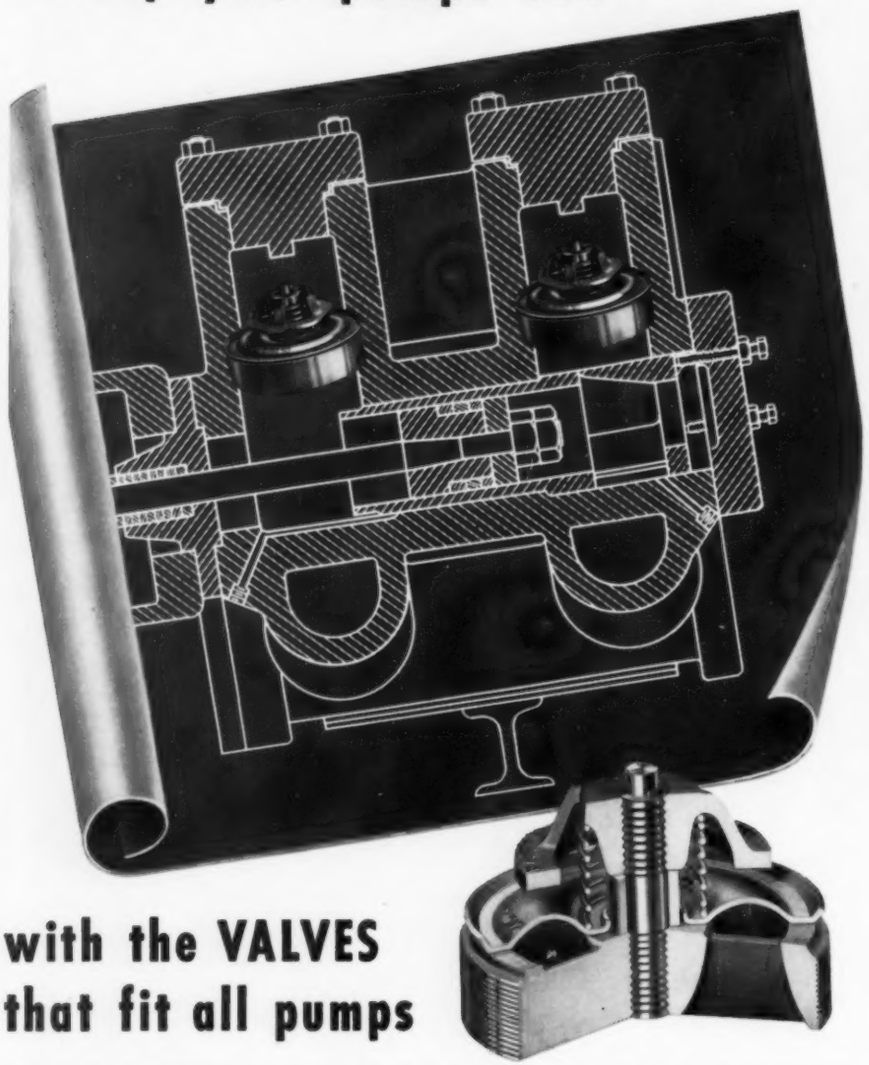

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DURABLA Pump Valves will operate freely under extremes of high or low temperature, with highly corrosive fluids, and in any position. They will handle vacuums of one micron or discharge pressures of thousands of pounds per square inch.

Standard equipment on many pumps, DURABLA Valve Units are made in fifteen sizes, designed to meet over 300 variations in installation requirements. They will fit any reciprocating pump, new or old.

A DURABLA engineer will be glad to help you work out a plant survey covering your valve requirements. Write for bulletin or engineering assistance.

DM-2

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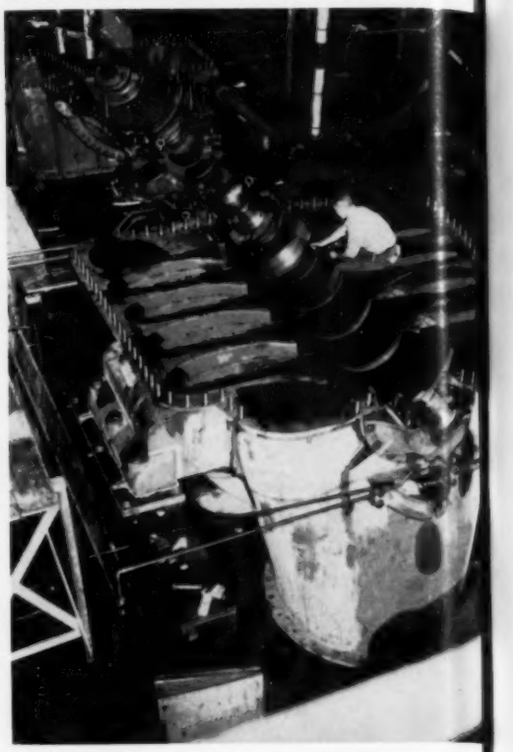

Cast by the cement bonded sand method, this 70,000 lb section was built by the foundry division of Chambersburg Engineering Co. for the De Laval Steam Turbine Co. The casting is one of two built for steam turbine driven blast furnace blowers. The compartments for the five-stage method of acceleration can be seen.

straight chrome and nickel-chrome series, silicon strip, copper and copper-base alloys. Aluminum splicing has already been perfected in certain grades.

Operation of the "Weld-a-Matic" Splicer is entirely automatic and requires no special welding skill on the part of the operators.

RUST PREVENTOR

▲ Now available from the American Sand-Banum Co., Inc., is a rust arrestor and preventor for use on all metals, new or old.

It is both a rust proofing primer and coating for new metals—a touch-up compound for rusted surfaces. Identified as "Rustend" it has exceeded the most rigid industrial and military specifications, and including 300 hour weatherometer test, more than nine months outside exposure test.

The compound is a transparent liquid that polymerizes upon drying

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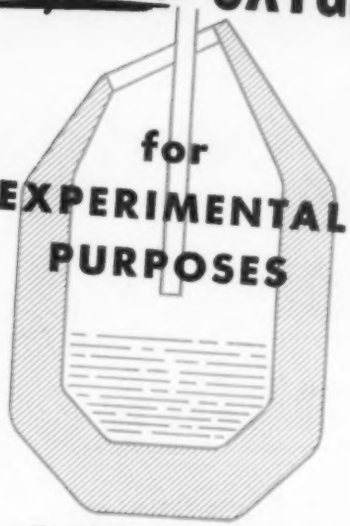
Surplus OXYGEN



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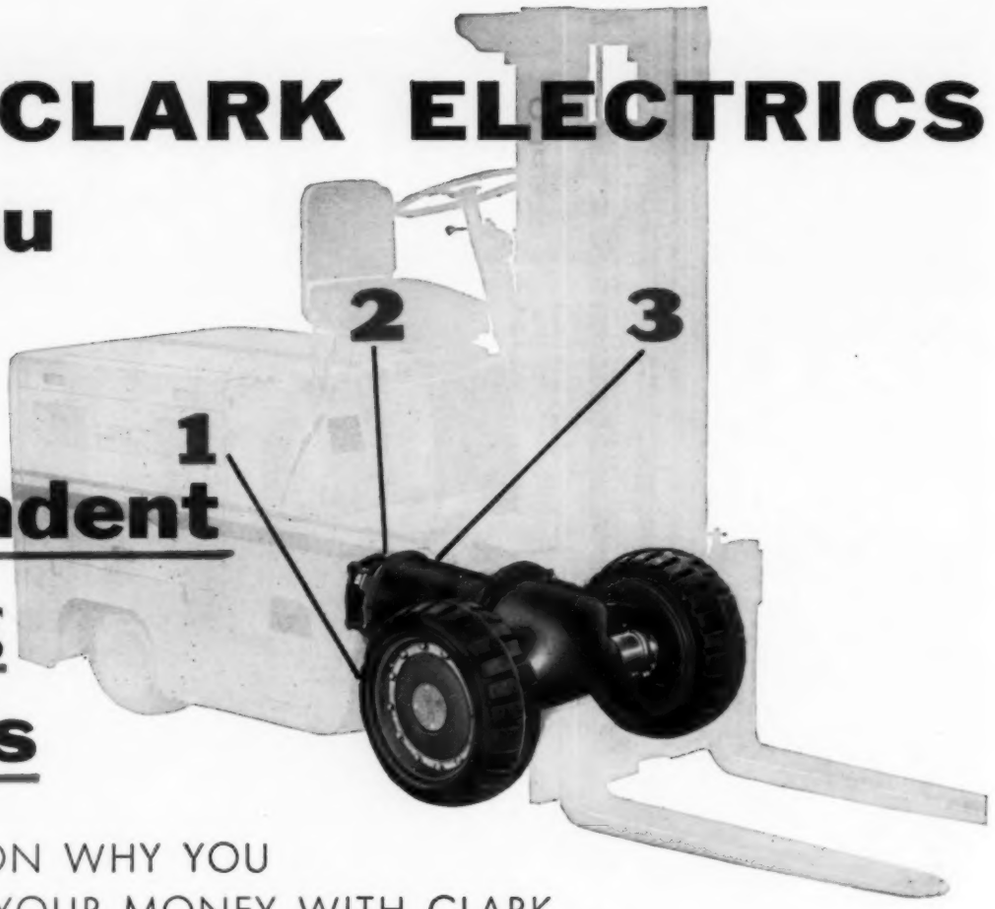

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with the rapidity of paint. It forms a flexible, resistant adhering film that contracts and expands with the metal, despite temperature variations. In the case of new metals adhesion is enhanced by weathering or etching. It contains no lead, avoiding such accompanying hazards.

It can be flowed, dipped, sprayed or brushed. It sets in not more than three hours and dries hard in not more than 24 hours, ready for painting if desired.

CAULKING PUMP

▲A new leverage system, just announced by Force Flo, Inc., provides easier, faster, more solid loading and reloading of caulking guns with caulking material direct from original refinery-filled containers.

The improved leverage also makes

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At Grand Rapids, Mich., a group of Chesapeake & Ohio officials examine a modified gondola car which was developed to bring blocking charges to a minimum for transporting steel safely. Equipped with movable partitions similar to those in a file drawer, the gondola car is suitable for either coil or bundle steel. Loading is done from each end toward the center of the car. When the cargo is in place, the movable stops are locked tight against it with U-bolts.

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it possible to load viscous materials such as heavy fiberous lubricants into guns—an operation often attempted but not successful with conventional type loaders.

The pump is a lever-action type. It is manually-operated and provides the utmost in safety and economy. Its rugged construction permits hard, every day, trouble-free usage. In actual operation the pump efficiently fills guns, effects cleaner, better work and saves operation time, material and effort. Change in weather or atmospheric conditions does not hamper the loader's performance.

WELDING PROCESS

▲ The new "Bernard-Arc" slag-gas shielded welding process, announced by the Bernard Welding Equipment Co., is a manually applied semi-automatic welding process which deposits electrode metal at a rate of 10 to 40 and more lb per hour. In other words, the new process is actually four or five hundred per cent more efficient than the present standard flux coated electrode process.

The "Bernard-Arc" electrode is tubular in construction and a flux is contained within the cavity of the tube. As the metal part of the electrode is melted by the heat of the arc and transferred through the arc to become part of the weld metal, the flux core also melts and is also transferred through the arc to become the refining and shielding blanket of slag. Both the metallic part of the electrode and the flux transfers through the arc in a finely divided ionized state. While in this finely divided form, the flux as well as the metal part of the electrode would become highly oxidized unless shielded from the surrounding air. It is to prevent oxidation of the electrode materials while transferring through the arc that a separate gas, not a product of the flux, is used for shielding the arc column.

The new torch is unique for the reason that the welding current, the arc column shielding gas, the water which keeps the torch cool, and the welding electrode, all pass through the handle of the torch. With this arrangement the torch is streamlined and is easily manipulated for accurately guiding the welding operation along the seams welded.

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Cut wire fence re-coating costs!

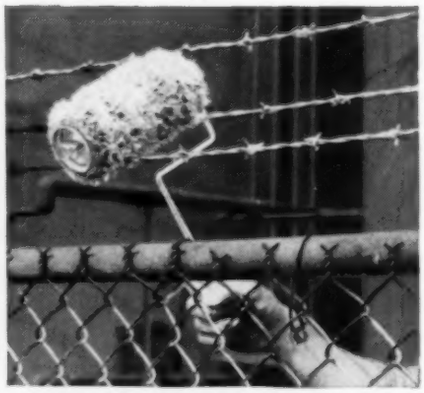
Users Report Savings of 30% to 40% With Rust-Oleum Extra-Long Nap Lamb's Wool Roller!

Special roller glides easily over wire sections. (Rusted sections have already been primed with Rust-Oleum 769 Damp-Proof Red Primer to Stop Rust.) Finish coat is Rust-Oleum 470 R.M. Aluminum.

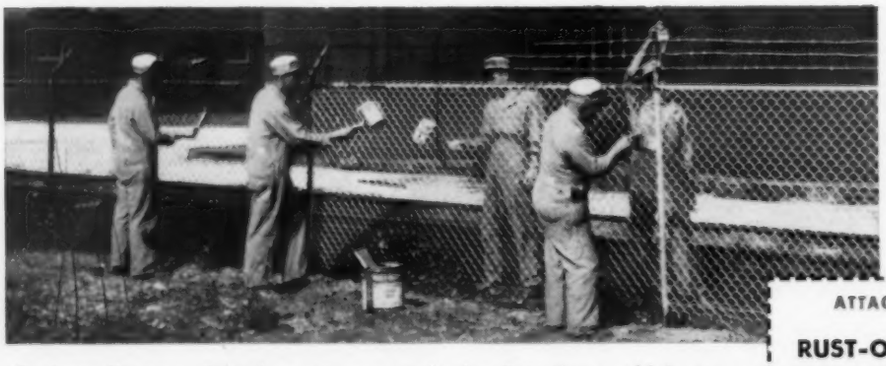
A *new, exclusive, different-type* roller! Greater diameter, specially selected skins, extra-long Lamb's Wool – all combine to give you more coverage faster and easier in the new Rust-Oleum Roller-Coating System.

Close-up shows how Extra-Long Nap Wool reaches around to coat approximately 70% of other side of fence at same time. Rust-Oleum's *exclusive* penetrating qualities saturate cross wire sections for desired mil thickness.

Man follows with "dry" roller on opposite side of fence to catch and use surplus "tears" and quickly coat remaining 30% of wire sections.



Even barbed wire sections can be roller-coated in one easy pass. 99% of the material is used on the fence – *not* on the workers, *not* on the ground.



On long distances of fencing, a 5 man production "team" can achieve even greater savings. The first man wirebrushes the surface to remove dirt, dust, rust scale, etc. The second man applies Rust-Oleum liberally by roller, coating the wire sections and barbed wire. The third man follows on the opposite side of the fence with a "dry" roller to catch and use the surplus. The fourth and fifth men work on opposite sides of the fence, brushing the pipe framework and the barbed wire arms. See how this new Rust-Oleum system can save you money. Attach coupon to your letterhead, mail *today*.

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POOLE FOUNDRY & MACHINE COMPANY

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INDEX TO ADVERTISERS

MAY, 1954

A

Adalet Manufacturing Co. 186
Aerovent Fan Co., Inc. 203
Aetna-Standard Engineering Co. 1
Air Products, Inc. 223
Ajax Flexible Coupling Co. 221
Alliance Machine Co. 163
Allis-Chalmers Manufacturing Co. 34, 35
American Brake Shoe Co., Electro-Alloys Division 140
American Brake Shoe Co., National Bearings Division 25
American Chemical Paint Co. 181
American Shear Knife Co. 183
American Wheelabrator and Equipment Corp. 188
Ampco Metal, Inc. 202
Anker-Holth Division, Wellman Engineering Co., The 146

B

Bailey Co., William M. 220
Bailey Meter Co. 51
Bedford Foundry and Machine Co. 161
Bethlehem Steel Co. 199
Birdsboro Steel Foundry and Machine Co. 143
Blaw-Knox Co., Machinery Division 2, 3
Blaw-Knox Co., Rolls Division 184, 185
Blaw-Knox Co., Union Steel Castings Division 136
Bliss Co., E. W. 52
Bonnot Co., 164
Bristol Co., The 162, 172
Brooks Oil Co. 204
Browning & Co., Inc., Victor R. 144
Bussmann Manufacturing Co. 138, 139

C

Carborundum Co., The 171
Cities Service Oil Co. 155
Clark Controller Co. 22
Clark Equipment Co., Ross Carrier Line, Industrial Truck Division 224
Cleveland Crane and Engineering Co. 48
Cleveland Quarries Co., The 182
Continental Foundry and Machine Co. 7
Crane Co. 32
Cutler-Hammer, Inc. Cover 2

D

Documentation and Licenses, Paris, France Cover 1
Dowell, Inc. 158
Dravo Corp. 11
Drever Co. 10
Durabla Manufacturing Co. 222

E

Electric Controller and Manufacturing Co. 5, 149, 216
Electric Service Manufacturing Co. 14, 15
Electric Storage Battery Co., The 208
Elliott Co. 166, 167

F

Falk Corp., The 21
Farrel-Birmingham Co., Inc. 169
Farval Corp., The Cover 3
Flinn and Dreffein Engineering Co. Cover 1
Fuller Co., The 192

G

General Electric Co. 41, 42, 43, 44
General Motors Corp., Hyatt Bearings Division 40

H

Hallden Machine Co. Cover 1
Harbison-Walker Refractories Co. 36
Hyde Park Foundry and Machine Co. 178

I

Ideal Industries, Inc. 226
Industrial Gear Manufacturing Co. 193
Insul-Mastic Corp. of America 187
Ironsides Co. 201

J

Jones Foundry and Machine Co., W. A. 217

K

Koppers Co., Inc. 47, 165, 190, 191

L

Leeds and Northrup Co. 8
Linde Air Products Co., Division of Union Carbide and Carbon Corp. 46
Link-Belt Co. 12, 38, 156
Lintern Corp., The 200

M

Mackintosh-Hemphill Co. 215
Mannesmann-Meer Engineering and Construction Co. 29
Manning, Maxwell and Moore, Inc. (Shaw Box Division) 4
McDanel Refractory Porcelain Co. 186
McKiernan-Terry Corp. 206
Mesta Machine Co. 232
Miles and Partner, John (London, Ltd.) Cover 1
Minneapolis-Honeywell Regulator Co. 16, 17
Morgan Construction Co. 157

N

National Carbon Co., Division of Union Carbide and Carbon Corp. 39, 196
Northern Engineering Works 179

O

Ohio Electric Manufacturing Co., The 168
Ohio Knife Co., The 170
Ohio Steel Foundry 174

P

Pacific Pumps, Inc. 177
Pennsylvania Transformer Co. 9
Pittsburgh Lectromelt Furnace Corp. 54
Plasteel Products Corp. 180
Poole Foundry and Machine Co. 230
Post-Glover Electric Co. 33
Pyle-National Co., The 203

R

Refractory and Insulation Corp. 214
Republic Flow Meters Co. 20
Roberts and Schaefer Co. 194
Rowan Controller Co. 173
Rust Furnace Co. 135
Rust-Oleum Corp. 228

S

Salem-Brosius, Inc. 37
Simmons Machine Tool Corp. 195
Smeeth-Harwood Co. 172
Spraying Systems Co. 172
Stamco, Inc. 203
Surface Combustion Corp. 30, 31

T

Taylor Chain Co., S. G. 225
Texas Co., The Cover 4
Timken Roller Bearing Co., The 6
Torrington Co., The, Bantam Bearings Division 213
Trabon Engineering Corp. 218
Truflo Fan Co. 176

U

Union Carbide and Carbon Corp., Linde Air Products Co. 46
Union Carbide and Carbon Corp., National Carbon Co. 39, 196
United Engineering and Foundry Co. 19
United States Graphite Co. 50, 227

V

Vaughn Machinery Co. 13

W

Wagner Electric Co. 189
Walker Process Equipment Co. 18
Wean Engineering Co. Cover 1
Wean Engineering Co. of Canada, Ltd., The Cover 1
Wean Equipment Corp. Cover 1
Wellman Engineering Co., The 147
Westinghouse Electric Corp. 151, 152, 153, 154
Wilson Engineering Co., Inc., Lee 205

Y

Youngstown Alloy Casting Corp. 27
Youngstown Foundry and Machine Co., The 45

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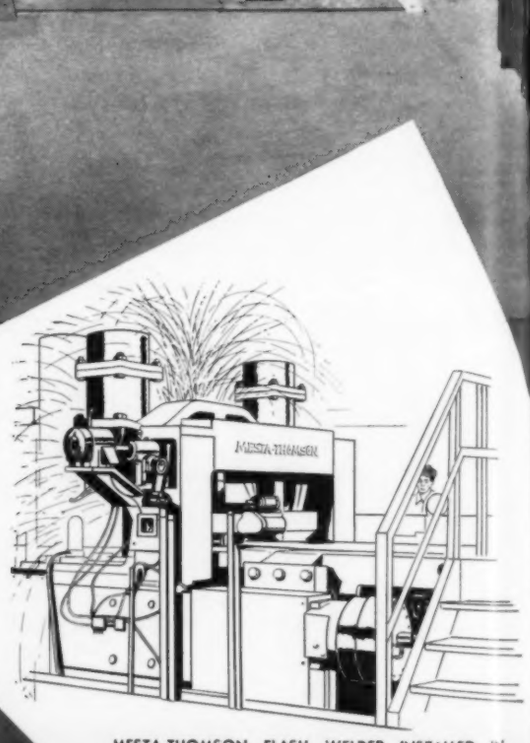

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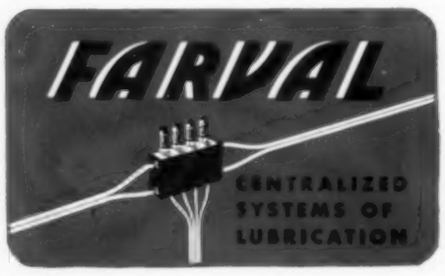

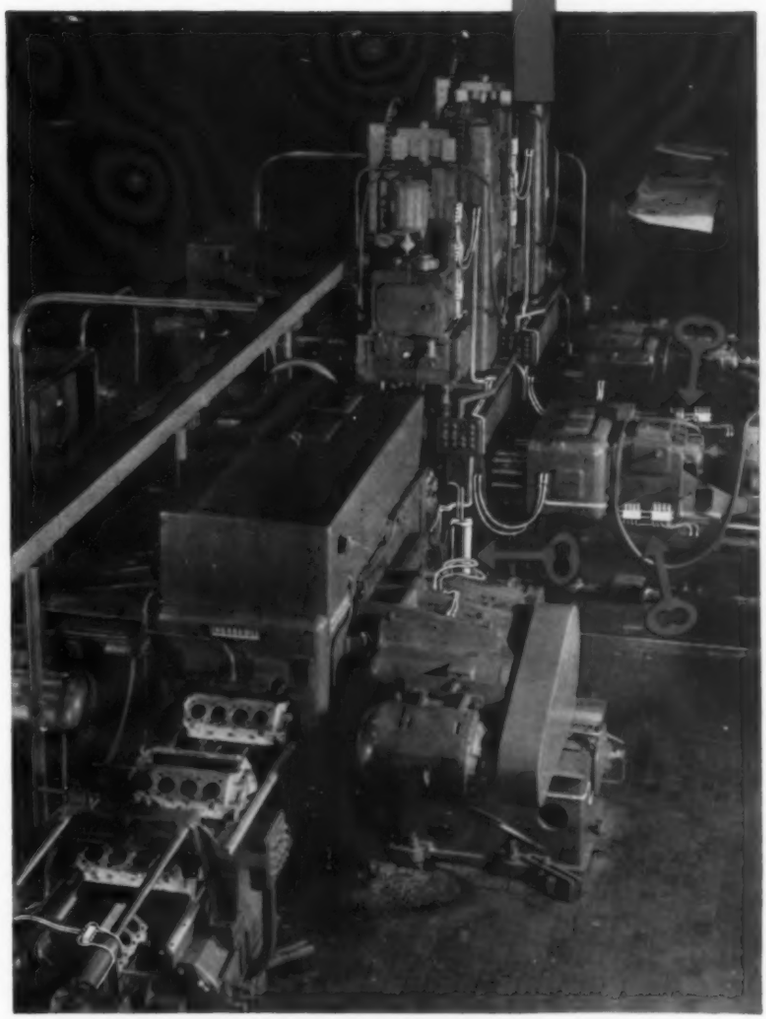

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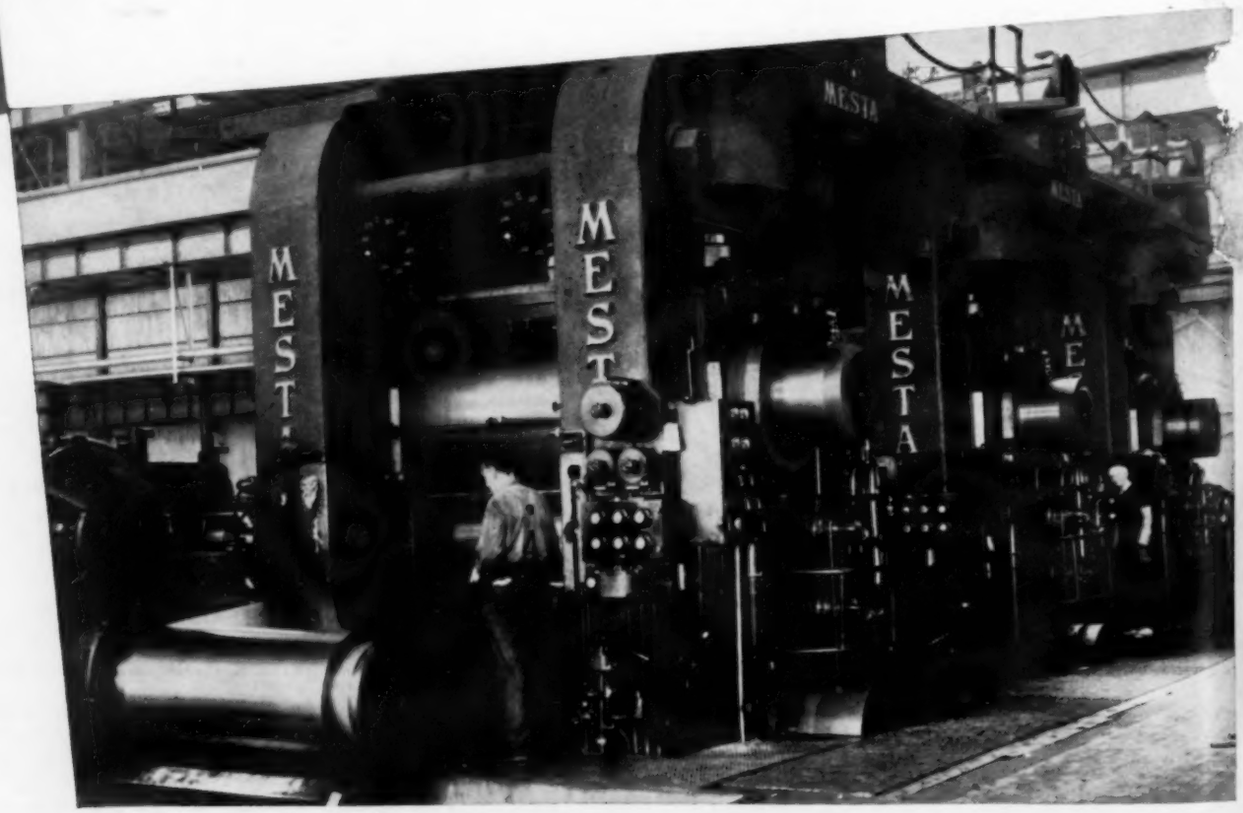

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